AIRCRAFT HYDRAULIC EQUIPMENT

BY

R. H. BOUND, A.F.R.Ae.S., A.M.I.A.E.

Technical Director
Dowty Equipment Limited
Cheltenham, Glos.

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PREFACE

Two years ago we published the first text book ever written on Hydraulic Actuating Equipment for Aircraft. Since then the demand has been so great that over 5,000 copies have been distributed throughout the world. This second edition includes much new material and brings the subject up to date. For obvious reasons no descriptions can be given of the latest developments which are of a secret nature, but those units now in production are fully described.

My Technical Director, Mr. R. H. Bound, A.F.R.Ae.S., A.M.I.A.E., has produced a book which, I am confident, will prove even more popular than his previous one.

G. H. DOWTY, F.R.Ae.S.,
Managing Director
Dowty Equipment Ltd.
(Formerly Aircraft Components Ltd.)

CHELTENHAM,
December, 1940.

PREFACE TO CANADIAN PRINTING

The second edition of "AIRCRAFT HYDRAULIC EQUIPMENT" was written and published in England during the trying days of late 1940. It is remarkable that even under tightening restrictions there were available one hundred copies for shipment to the then newly-organized Canadian Dowty Company. These books were widely distributed throughout the Canadian aircraft industry and the R.C.A.F., and the demand for them has been far beyond the available supply.

In bringing out this printing to meet the Canadian demand, it is, therefore, fitting that we should include one thousand copies for shipment to our English company in partial recognition of the invaluable technical guidance and assistance they have given us during our rapid growth to the present position we occupy in the aircraft industry of this country.

T. R. WINGATE, A.M.I.MECH.E.
Vice-President and General Manager,
Dowty Equipment (Canada) Limited

MONTREAL, August, 1943.

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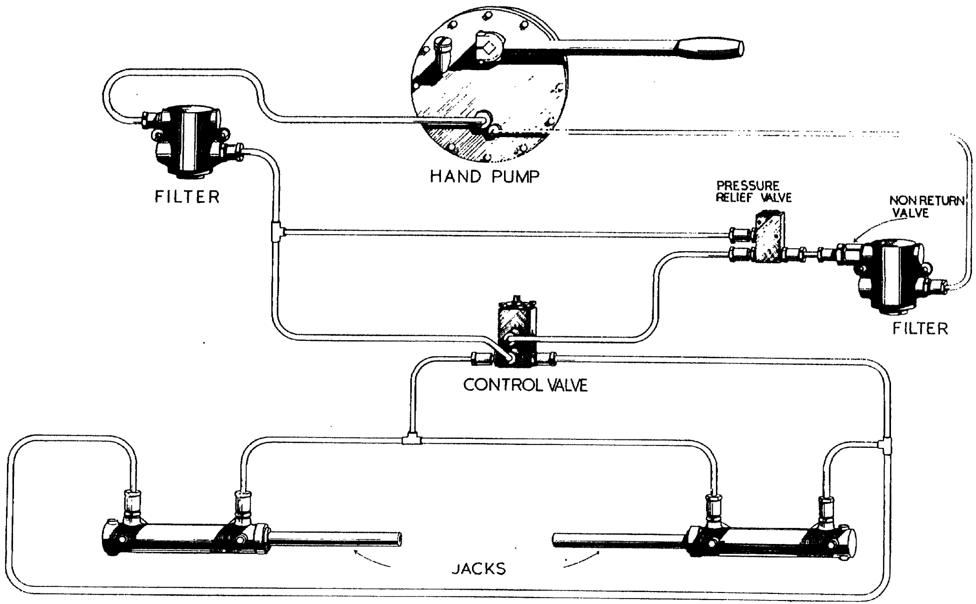


Fig. 1. Simple Hand Pump Hydraulic Installation

AIRCRAFT HYDRAULIC EQUIPMENT

CHAPTER I

THE actuation of retracting undercarriages, tail wheels, flaps, gun turrets, firing gear, bomb doors, control trimming tabs, engine cowl gills, etc., by means of hydraulic jacks, has become increasingly popular during the past few years, and this method of operation has been adopted by practically all aircraft constructors.

Probably the chief reason for this popularity is the fact that one central power unit, namely the pump (which may be engine or hand operated, or may be a self-contained electrically powered unit) can control all the components mentioned without the employment of torsion shafts, push rods or other mechanical power transmission means.

Again, the hydraulic control system offers an extremely simple means of gearing up or gearing down between the power unit and the operated device without resort to worm shafts, gear wheels, or lever combinations, for it is only necessary to vary the piston areas of the different operating units to obtain the desired gear effect.

There are three main units common to all aircraft hydraulic installations ;

1. A pump supplying oil under pressure.
2. A valve controlling the direction of flow through the pipe lines, and
3. Jacks operating the various components.

Fig. 1 illustrates the simplest form of hydraulic installation suitable for operating either a retracting undercarriage or wing flaps.

This installation comprises a hand operated pump, a two-way control valve and a pair of jacks. The pump delivers oil under pressure to the jacks via the control valve which is so constructed that it allows the operator to change the direction of flow in the jack pipe lines, thus permitting extension or contraction of the jacks at will.

Oil filters are provided and a pressure relief valve is incorporated to prevent the flaps being lowered at excessive flying speed. This valve also permits the flaps to blow up if the speed of the aircraft is unduly accelerated.

Constructional and operational details of the various units will be given later.

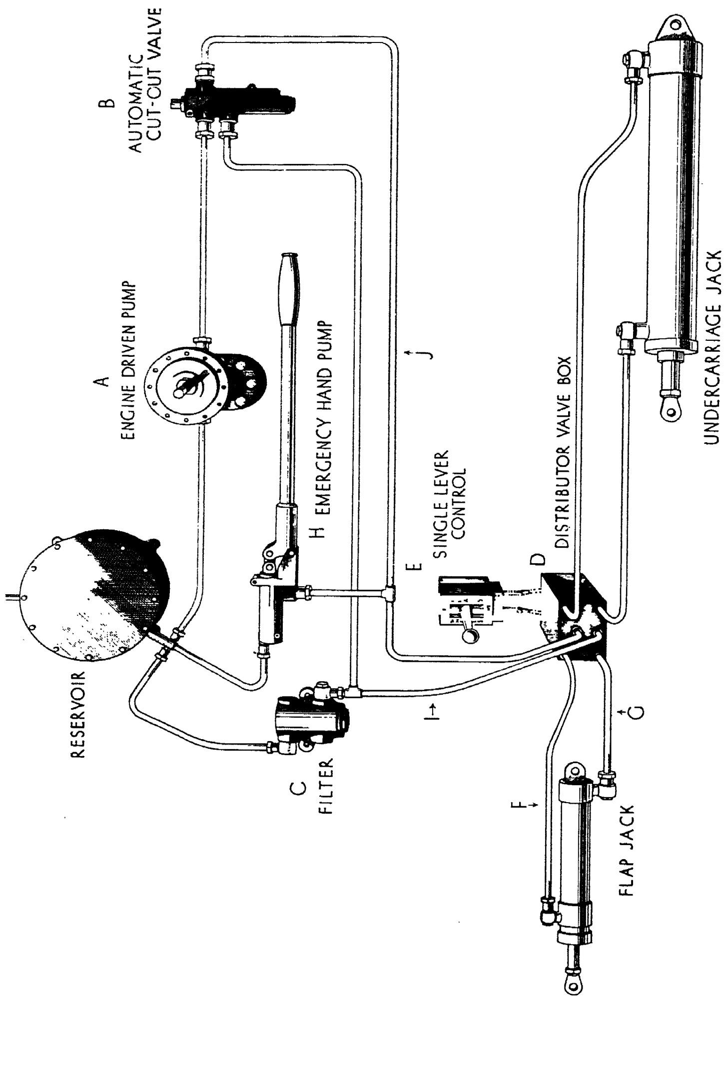


Fig. 2. Dowty Installation with Engine Driven Gear Pump

Fig. 2 illustrates a simple hydraulic installation in which the pressure supply is provided by an engine driven pump.

For simplicity, only one undercarriage jack and one flap jack are shown in the diagram, but tappings may be taken off the pipe lines to operate any number of jacks.

When the engine is running, the pump (A) delivers oil continuously to an automatic valve (B), which normally allows the oil to flow direct to the reservoir via filter (C). Under these conditions the pump is idling at no pressure.

The pilot is provided with a single lever control (E) for operating the undercarriage and flaps.

To avoid bringing pipe lines into the cockpit, this control lever is connected to the distributor valve box (D) by remote controls such as push rods. Operation is as follows. To lower flaps, the control lever is moved out of neutral to the gate position labelled " Flaps down " and this actuates the distributor valve, thus connecting pipe (G) to pressure pipe (J), and pipe (F) to the return pipe (I). The automatic valve (B) instantly goes into action and the pump supplies oil under pressure to the flap jack. When the jack piston reaches the end of its stroke, the automatic valve cuts off the supply and the pump then circulates oil under no pressure to the reservoir.

A detailed explanation of the working of the cut-out valve will be given later.

To raise the flaps the lever is moved to the opposite end of the gate labelled " Flaps Up," and by this means the pipe (F) is connected to the pressure pipe (J) the pipe (G) is connected to the return pipe (I), and the cut-out valve again diverts the pump delivery to the jack circuit. It should be noted that in this system the flap jacks may be stopped at any point in their travel by returning the control lever to the neutral position, thus enabling the pilot to set the flaps at any desired angle.

The hand pump (H) is provided as a stand-by in case of failure of the engine driven pump.

To prevent excessive pressure in any pipe line due to temperature variation, the distributor unit is provided with automatic relief valves to compensate for variations in volume.

Further details of these units will be given in a later chapter.

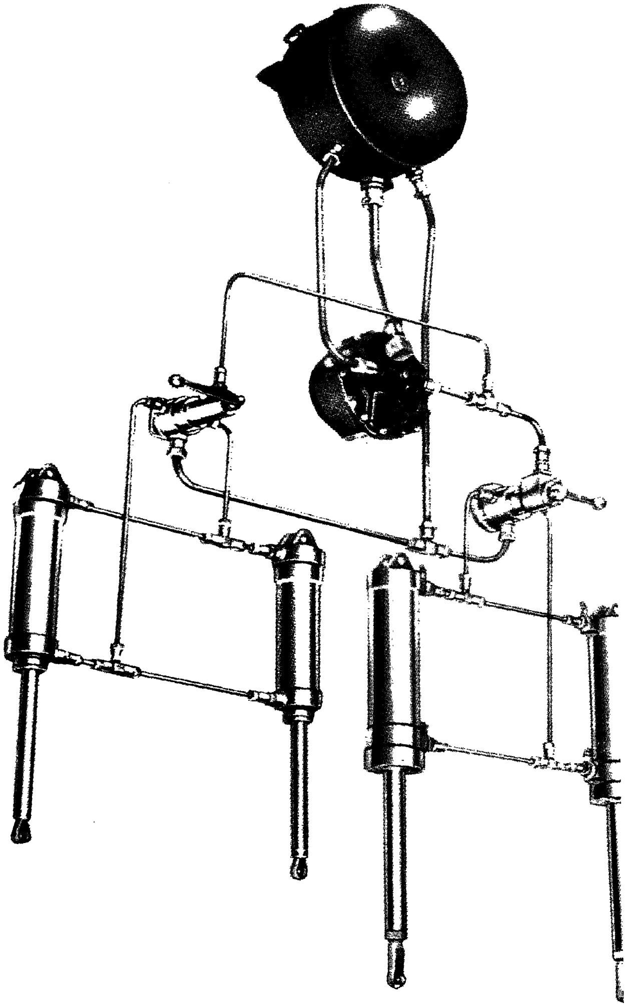


Fig. 4. Dowty "Live-Line" Installation

The latest development in hydraulic installations powered by engine driven pump is illustrated in Fig. 4. This is the "Live Line" system, using the Dowty Live Line pump, which is automatic in action and eliminates the need for cut-outs and accumulators. It reduces the number of hydraulic items to a minimum and thereby simplifies installation and operation and reduces vulnerability. Delivery from this pump ceases at a predetermined pressure and recommences immediately the pressure falls below this predetermined figure. Delivery is constant over a wide range of r.p.m.

Delivery pressures up to 3,000 lbs. per square inch can be obtained and cooling is effected by constant oil circulation through the pump casing.

An advantage of this system is that the speed of jack operation can be adjusted to suit the particular requirement of the service they perform. This is accomplished by a restriction fixed or adjustable in one of the common jack lines.

The effect is to produce a high pressure at the pump, causing it to react to an intermediate position, with correspondingly reduced delivery. The jacks therefore move more slowly.

This pump is described fully in the next chapter.

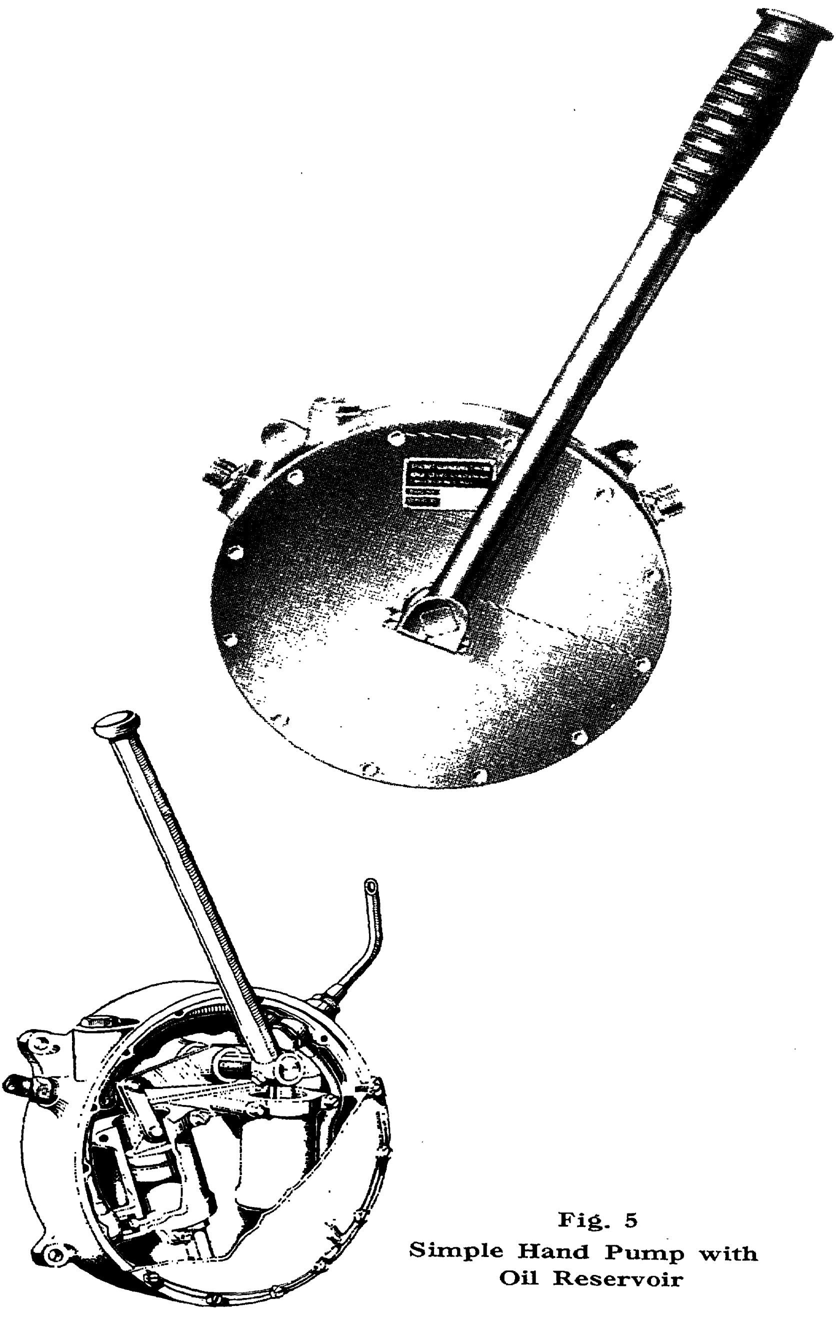


Fig. 5
Simple Hand Pump with Oil Reservoir

CHAPTER II

PUMPS

These units may be divided into two main types :—

1. The hand operated pump which may be a stand-by unit for emergency use or may be the sole source of power.

2. The engine driven unit which is usually mounted directly on the engine or may be mounted on an extension bracket and driven by a shaft from the engine.

HAND PUMPS

In all installations employing an engine driven pump it is usual also to provide a hand pump for the following reasons :—

(a) In the event of the engine pump failing, the hydraulic units can be actuated by the hand pump.

(b) Flaps and other units can be operated on the ground when the engine is not running.

(c) Pipe lines and all joints can be pressure tested.

(d) Bomb doors can be opened for loading the racks without running the engine.

In hand pump units the oil reservoir is either incorporated in the pump body, or forms a separate unit coupled to the pump by suitable pipe lines.

A combined hand pump and reservoir is illustrated in Fig. 5, which shows an external view and also the internal construction.

A hand pump of the non-reservoir type is illustrated in Fig. 6, and this unit embodies the characteristics of a double acting pump in a very compact body.

It also incorporates a non-return valve and a relief valve which can be set to blow off at any required pressure. The working principle of this pump will be understood from the diagrammatic section shown in Fig. 7. The non-return valve and relief valve have been omitted for the sake of clearness.

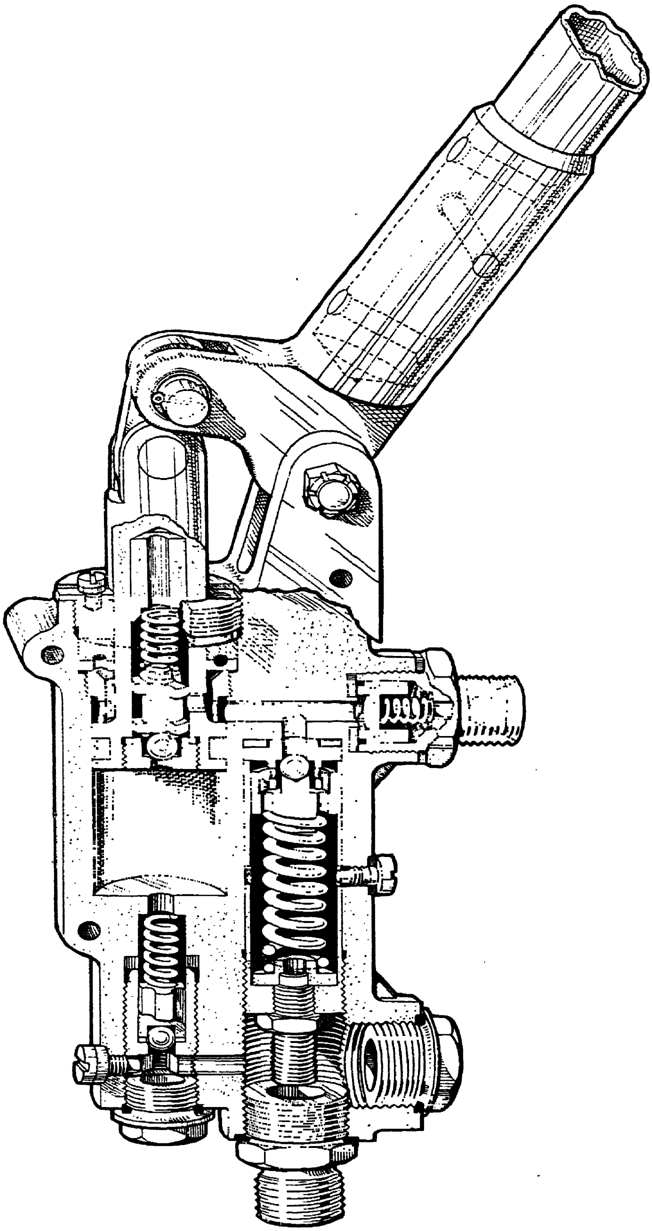


Fig. 6. Hand Pump with Relief Valve and Non-return Valve

Referring to this illustration, the oil space in the cylinder is indicated by the black areas.

When the handle is moved in the direction towards the right-hand side of the page a charge of oil is drawn in below the piston. On the reverse stroke this oil is expelled through the ball valve in the piston into the space above.

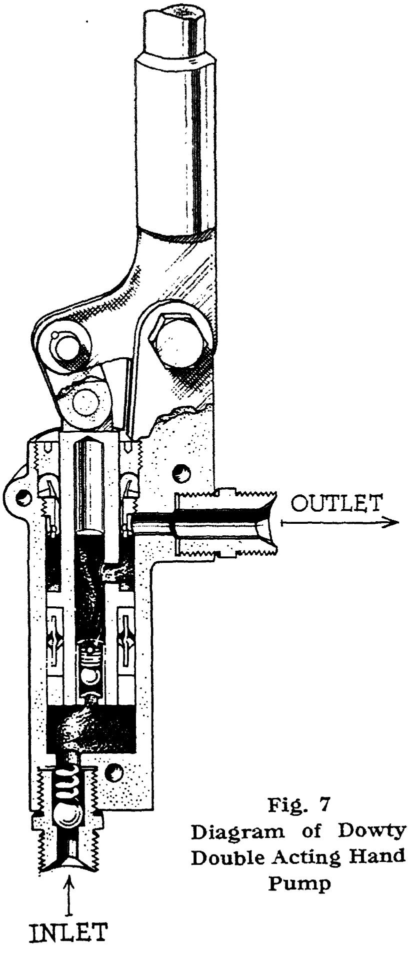


Fig. 7
Diagram of Dowty Double Acting Hand Pump

The cross sectional area of the piston rod is exactly half that of the cylinder, consequently half the displaced volume of oil is forced into the delivery pipe.

The other half remains above the piston, ready to be delivered on the next up stroke, when a further charge is drawn into the cylinder.

ENGINE DRIVEN PUMPS

Many engine driven pumps have been developed during the past few years for use with aircraft hydraulic equipment, including single and multi-stage gear pumps, piston pumps, semi-rotary pumps, vane pumps, etc. It is desirable that engine driven pumps should give practically continuous delivery as against pulsating delivery.

It is beyond the scope of this book to describe all these types and this subject has been dealt with very effectively in aeronautical publications from time to time.

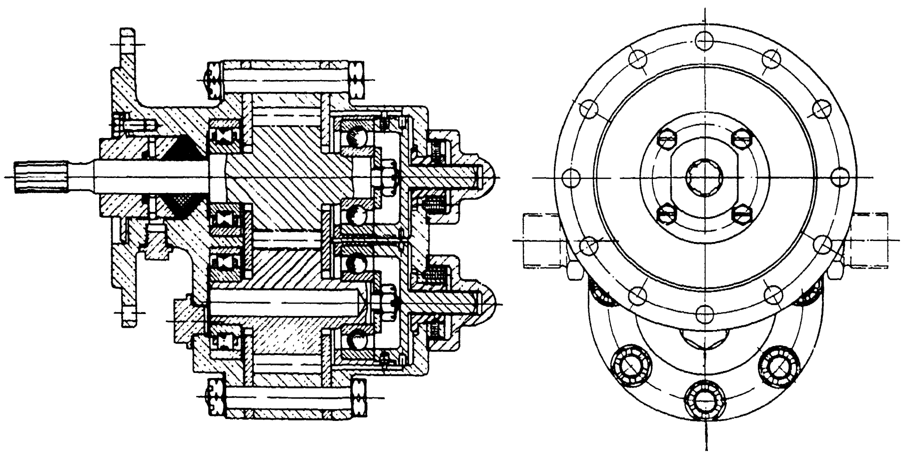


Fig. 8. Engine-driven Gear Pump

However, this work would be incomplete without some information on these units and Figs. 8 to 14 give particulars of two engine driven pumps used on modern installations.

Fig. 8 shows a section through the "Dowty" gear pump. The body of this pump is of a light alloy having a co-efficient of expansion similar to that of the steel gear wheels, thus maintaining constant clearances between the working parts at all temperatures.

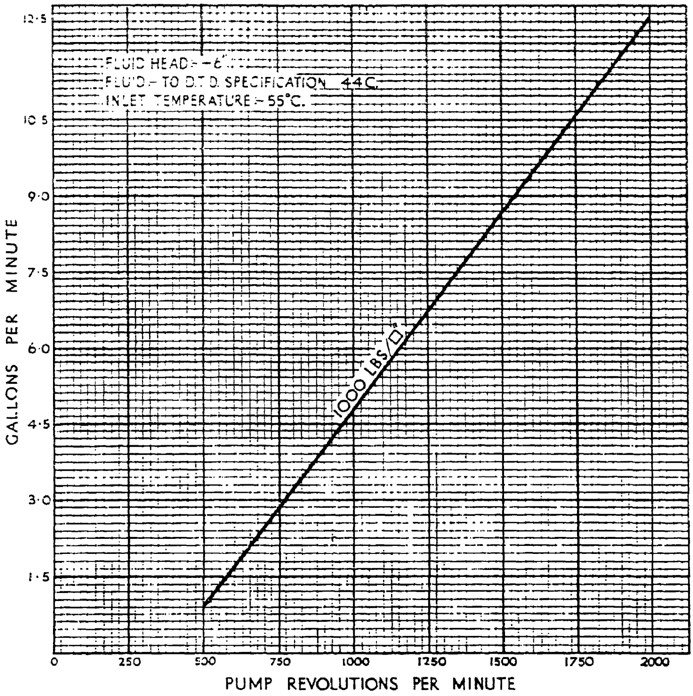


Fig. 9. Dowty Gear Pump Delivery Graph

Fig. 9 shows the output curve for this pump.

This unit has been designed to give high deliveries to meet the demands of gun turrets operation, and high pressures to suit retracting undercarriage equipment.

One particular advantage of this pump is its high delivery at low r.p.m., which enables the undercarriage and flaps to be operated rapidly when the engine is throttled back for landing.

Fig. 10 illustrates the Dowty " Live-Line " pump referred to in Chapter 1.

The operation of hydraulic services at higher pressure permits reduction in size and weight of all units and also permits the use of smaller pipes, with a consequent saving in weight of pipes and oil carried.

For high working pressures it is necessary to utilise the solid displacement piston type pump rather than gear wheels.

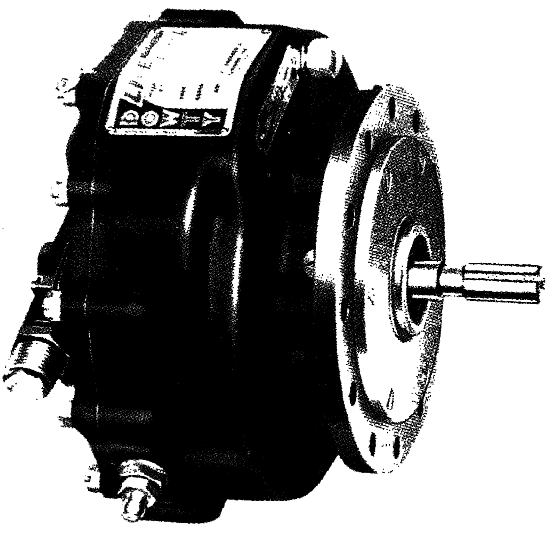


Fig. 10. Dowty " Live-Line " Pump

The " Live-Line " is a multi-piston pump and is made in a range of types giving various deliveries.

It has three pipe connections, two from the reservoir and one delivery line which is always under pressure and called the ' Live '-Line.

The working principle is explained in Figs. 11 and 12.

During operation of any service, the pressure in the 'Live'-Line is determined by the working pressure required by the operated unit. At the completion of an operation the pump pressure rises to the pre-set maximum (which may be as high as 3,000 lbs. per square inch) and then ceases delivery. A flow is maintained through the pump casing and centrifuge return pipe to the reservoir to cool the pump.

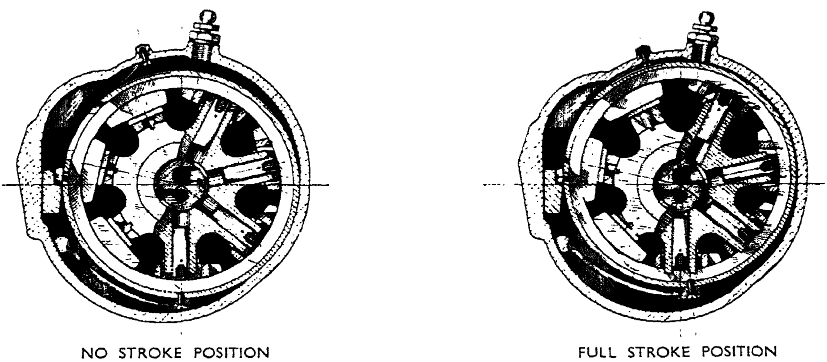


Fig. 11. "Live Line" Pump in Idling and Full Delivery Positions

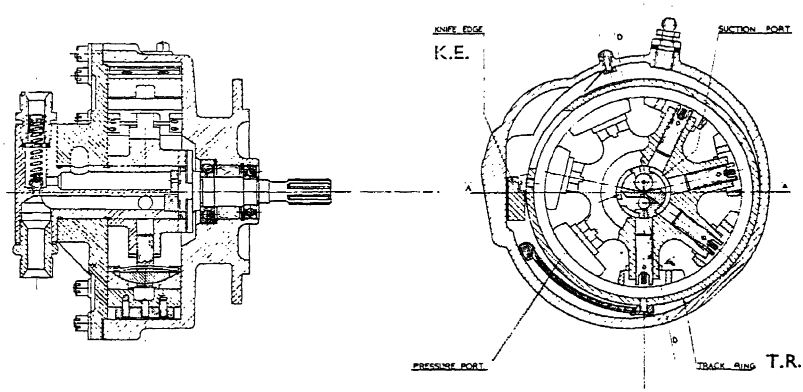


Fig. 12. Sections through "Live-Line" Pump

The pump comprises a casing through which passes a fixed shaft forming a bearing for a seven cylinder rotor block. Each cylinder is provided with a sliding piston carrying a pivoted slipper bearing on the inner diameter of the track ring (T.R.) The track ring is pivoted on a knife edge (K.E.) about which it can turn from a position concentric with the fixed shaft to a position eccentric with the same.

When the track ring is concentric the pistons have no stroke; when it is in the position of maximum eccentricity they have their maximum stroke.

A curved leaf spring which acts as an Euler Strut urges the track ring over to the maximum stroke position; this strut collapses when the maximum high pressure is reached, allowing the track ring to swing back to the no stroke condition.

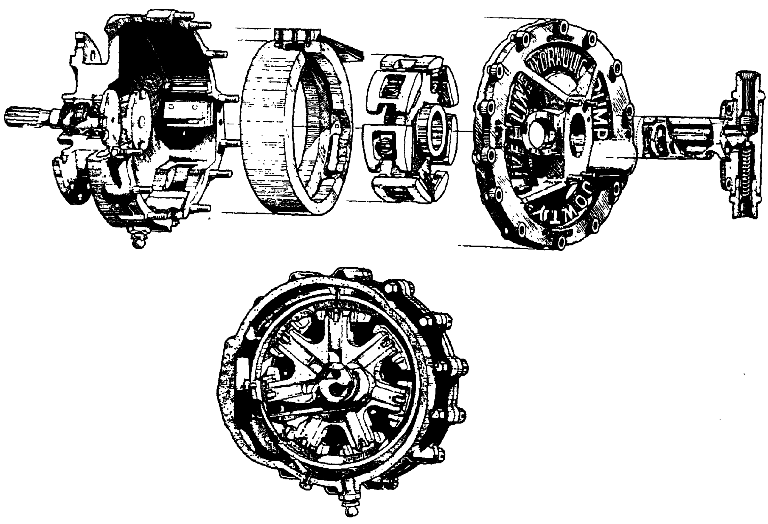


Fig. 13. Construction of "Live-Line" Pump

The track ring acts upon the pistons and they react against it. The resultant balance of forces is dependent on the pressure in the 'Live'-Line and when this reaches its maximum the track ring moves rapidly from the full stroke to the no stroke position.

Oil from the reservoir enters the case near the centre, through the suction connection. The rotation of the cylinder block sets the oil in motion and it passes by centrifugal force through a duct into a channel formed in the casing and so back to the centre shaft, and from here to the suction port (under the pistons moving outwards) thus supercharging the cylinders. Any excess flow is by-passed to the centrifuge return to reservoir.

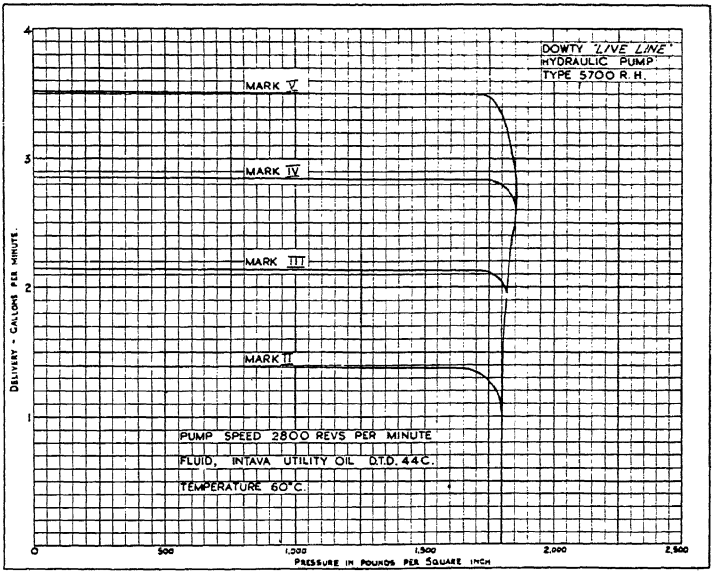


Fig. 14. Output Graph of "Live-Line" Pump

The track ring can take up positions intermediate between zero and maximum eccentricity sufficient to maintain flow to feed at any required rate.

This pump can maintain continuous delivery at high pressures. An exploded view of this unit is shown in Fig. 13, and delivery output in Fig. 14.

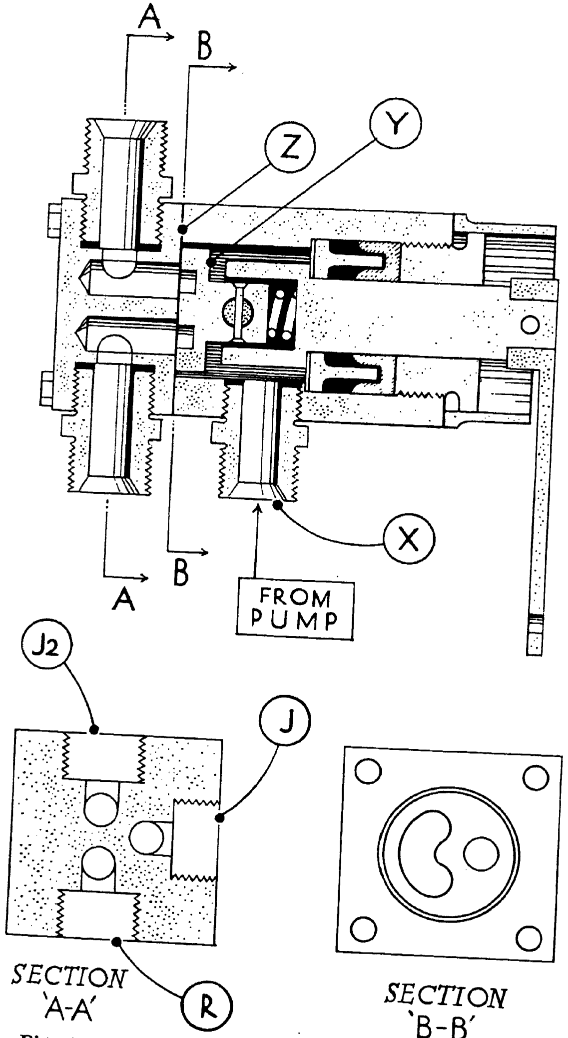


Fig. 15. Sections through Rotary Control Valve

CHAPTER III

CONTROL VALVES

NUMEROUS types of control valves have been developed and some typical examples will be described.

Figs. 15 and 16 illustrate a rotary type valve which is used on many present day aircraft. Oil from the pump is fed in through the upper pipe connection (X) and through the disc valve (Y). This disc is held in contact with the valve block (Z) by a light spring. The disc and valve block are made from steel, case hardened and ground.

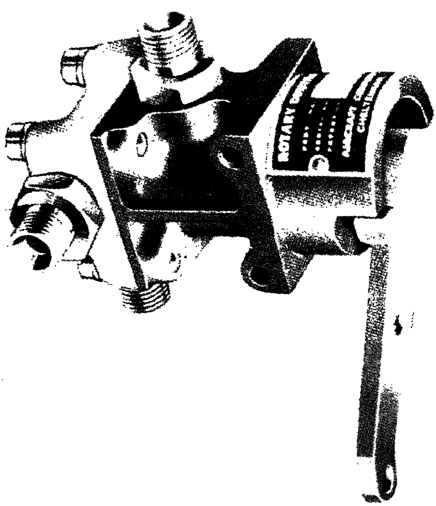


Fig. 16. Rotary Control Valve

The spring contact pressure is supplemented by the oil pressure acting on the disc so that the greater the pressure tending to cause leakage, the greater the pressure between the disc and seat. Oil is delivered through port (J) to one end of the jack and simultaneously oil from the opposite end is swept back through connections (J2) and (R) to the reservoir. By rotating the disc valve the direction of flow through the pipes is reversed.

This valve construction is illustrated in the " cut-away " diagram, Fig. 17.

Another type of valve is shown in Fig. 18. This comprises a body carrying a multi-cam shaft for operating spring loaded poppet valves.

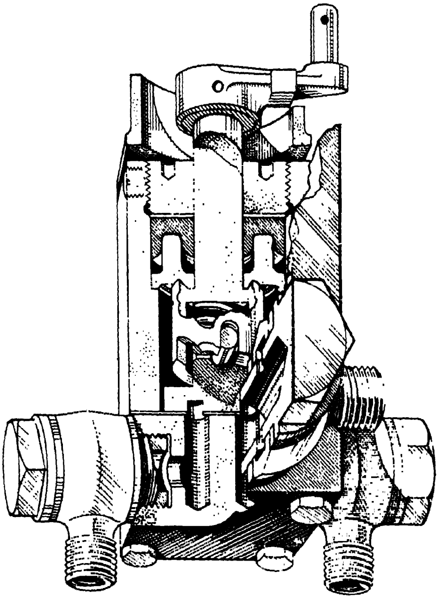


Fig. 17. Dowty Rotary Control Valve

The valves have synthetic rubber inserts and sit on faces machined in the valve chest body.

Rotation of the camshaft lifts the valves from their seats and when the lever is returned to the neutral position the pipes communicating with the jacks are closed by the spring loaded valves, providing positive hydraulic locks.

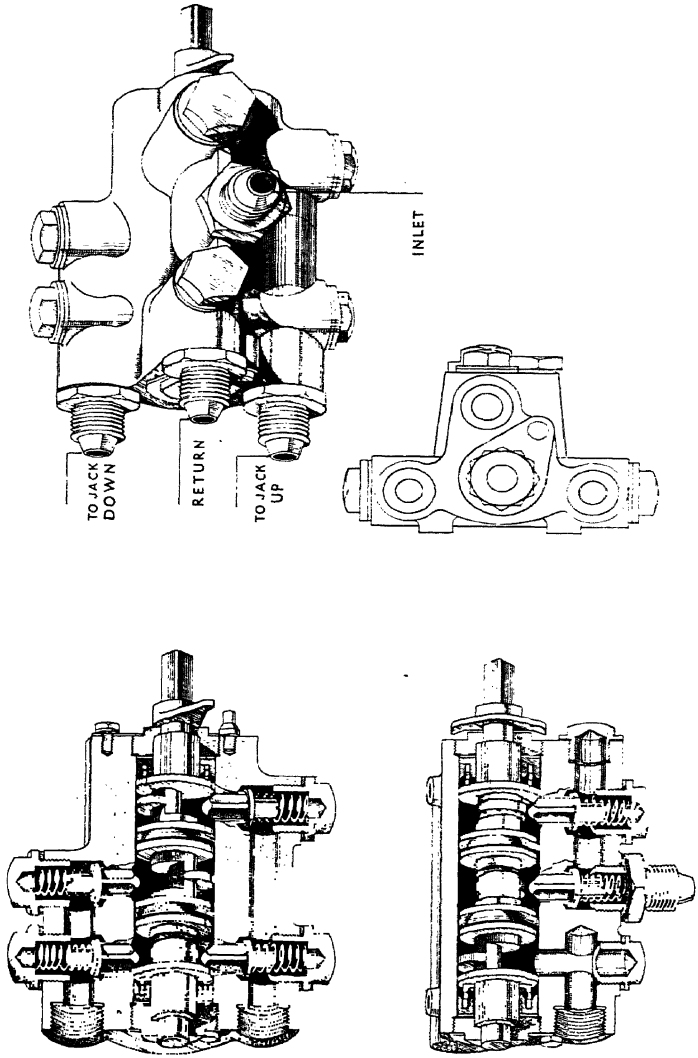


Fig. 18. Dowty Cam Operated Control Valve

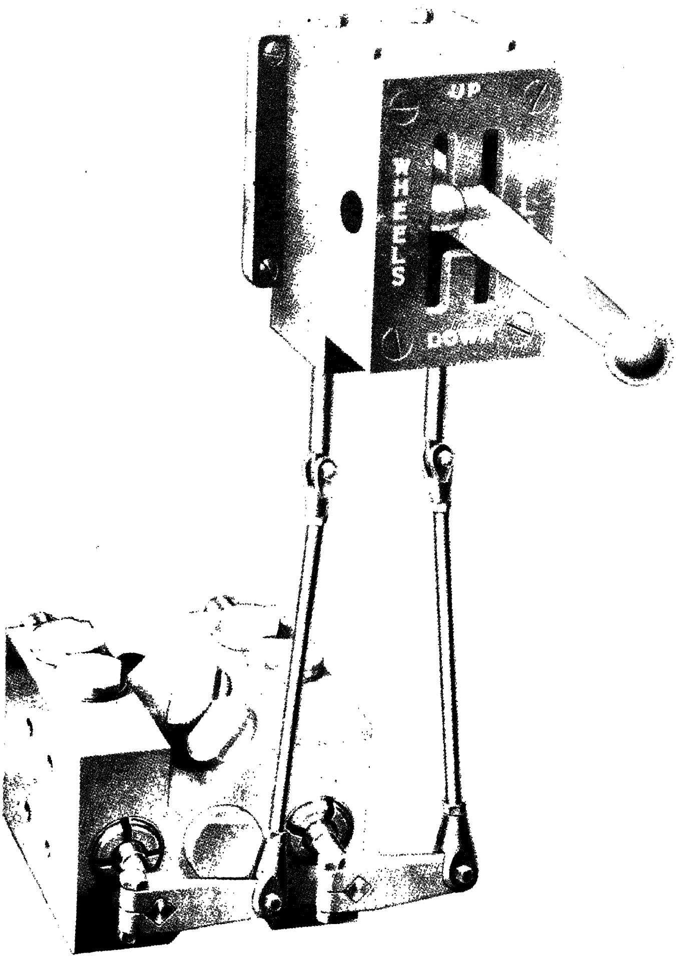


Fig. 19. Dowty Single Lever Control

A third type of valve with a remote control unit is shown in Fig. 19. This combination has much to commend it. The valve is designed to operate two separate services, such as retracting undercarriage and flaps, by means of a single control lever. This lever moves in a gate which is provided with slots suitably inscribed, such as "Wheels up," "Wheels down" and "Flaps up" and "Flaps down." This control valve consists of a body fitted with two multi-cam shafts and poppet valves controlling the flow of oil to either the undercarriage or flap circuit.

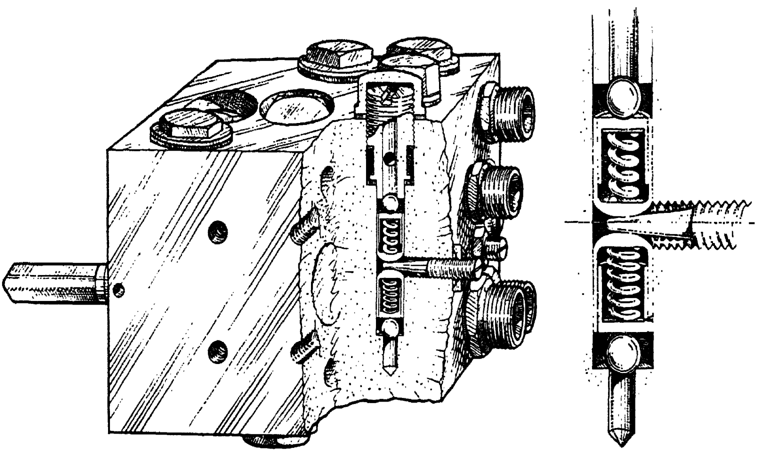


Fig. 20. Relief Valves in Control Box

This unit can control two circuits operating under different pressures. For example, the operating pressure in the undercarriage system may be 700 lbs. per square inch, and the flap system 900 lbs. per square inch.

Relief valves govern the maximum pressure in each circuit.

Setting of these relief valves is obtained by means of a tapered needle provided with a screw adjustment. This needle is offset from the centre line of the screw so that the pressures applied to the relief valve springs may be varied.

Fig. 20 shows how this is accomplished.

Some of the earlier hydraulic installations incorporated a manually operated valve in addition to the selector valve. In such a system it was necessary to select the service required (such as undercarriage " up ") and then actuate another valve to admit power to the selected circuit.

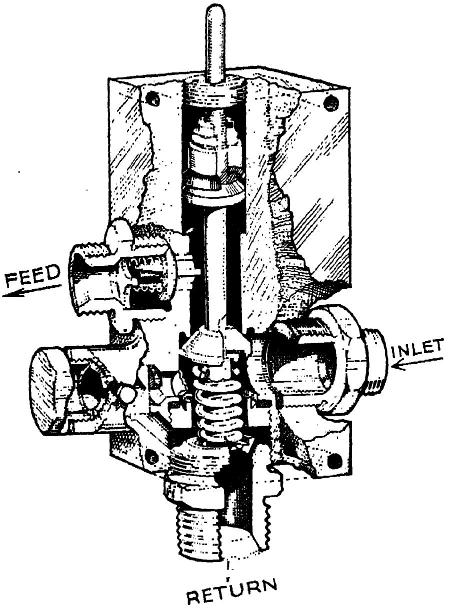


Fig. 21. Construction of Power Valve

This power valve is illustrated in Fig. 21. Normally the oil has a free passage through the valve from inlet to return side, but when the plunger is depressed this outlet is blanked off and oil is diverted past the valve and out through the feed connection.

A relief valve is incorporated to prevent excessive pressures when the jacks have completed their travels.

PRE-SELECTOR VALVES

A pre-selector control system is illustrated in Fig. 22. This control enables the pilot to set the flaps in any desired position for take-off and landing conditions, and also to steepen or flatten the gliding angle at will.

Automatic synchronisation can be provided for several flaps, as for example those fitted to a centre section and two outer wings

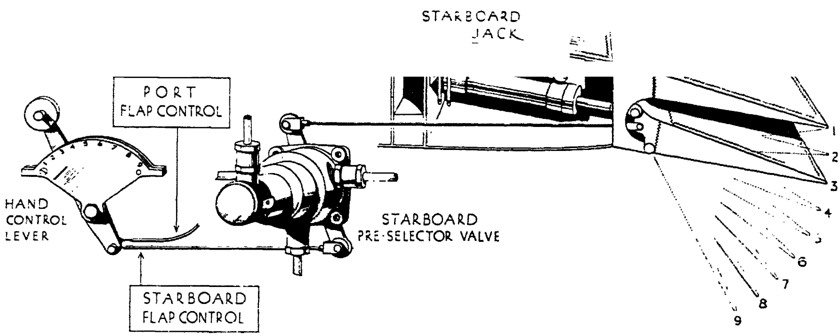


Fig. 22. Dowty Pre-selector Control System

The pre-selector valve is provided with two levers, one connected to the hand control unit and the other coupled to the flap lever. The levers on the valve are attached to two concentric spindles which control disc valves. When the hand lever is moved, oil flows through the pre-selector into the jack and when the flap has reached a position corresponding with the setting of the hand lever, the valve cuts off the oil supply and the flap is locked in that position.

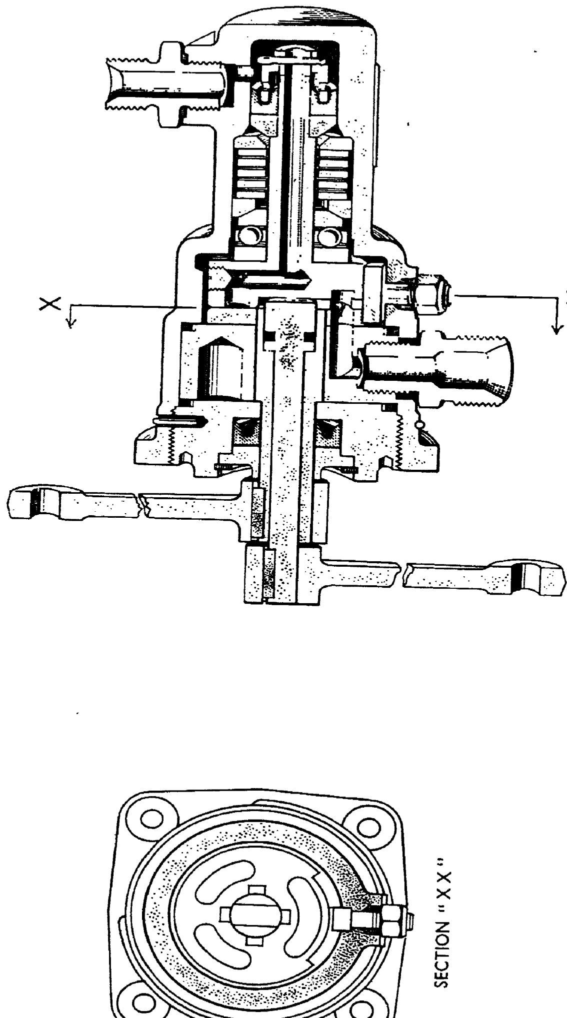


Fig. 23. Sections through Pre-selector Valve

Fig. 23 shows a section through a pre-selector valve. This control system has wide application for the operation of radiator shutter jacks, landing lights, etc., where intermediate settings are required.

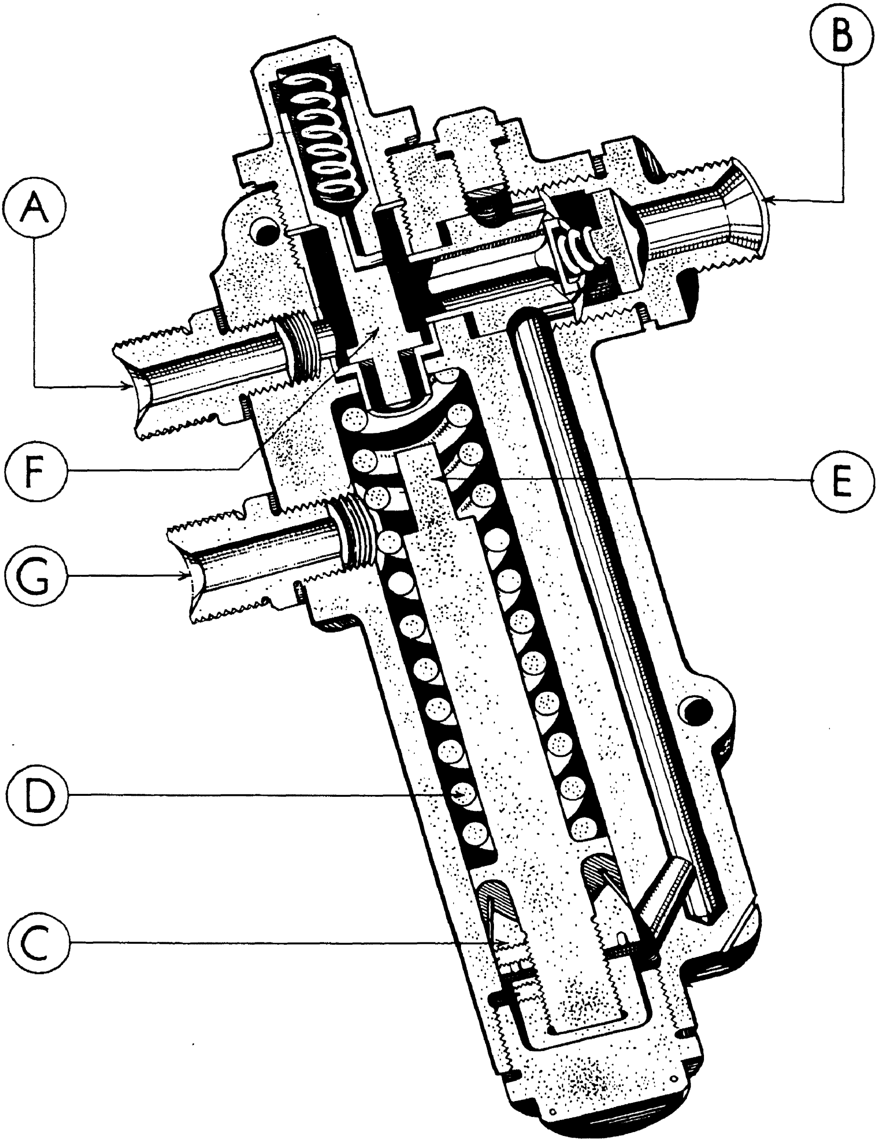


Fig. 24. Automatic Cut-out Valve

CHAPTER IV

AUTOMATIC CUT-OUT VALVE

IT is only necessary for the engine driven pump to supply fluid under pressure during operation of any service. On completion of this service it is preferable that the fluid supply be diverted to the reservoir and the pump output pressure reduced to zero.

This requirement is met by the automatic cut-out valve which enables the pump to idle at all times except when any hydraulic service is operated.

Fig. 24 shows a section through a cut-out valve. Oil is fed from engine pump to connection (A) and during jack travel passes through connection (B) via the control box to the selected pipe line. When the jacks reach their limit of travel, pressure rises momentarily and reacts on piston (C), causing this to move and compress spring (D). An extension (E) on the piston lifts valve (F) allowing oil from the pump to escape through connection (G) to reservoir. The pump is then idling and the only pressure in the circuit is due to hydraulic friction in pipe lines and filter.

Meanwhile, the valve (F) is held off its seat by oil pressure behind piston (C). This condition holds good until the jacks are operated in the reverse direction, or some other service is actuated.

When this occurs the pipe lines holding high pressure are opened to reservoir with consequent loss of pressure behind piston (C), which then returns to its original position (under the influence of the spring), thereby allowing valve (F) to reseat and close the return line to reservoir.

Oil delivered by the pump then passes through the cut-out and into the control valve, to actuate the jacks again.

This cut-out may be regulated to lift valve (F) at any desired pressure, limiting the maximum pressure in the circuit to any desired figure.

Fig. 25 shows conditions in the cut-out valve during travel of the jack piston and Fig. 26 after the stroke is completed.

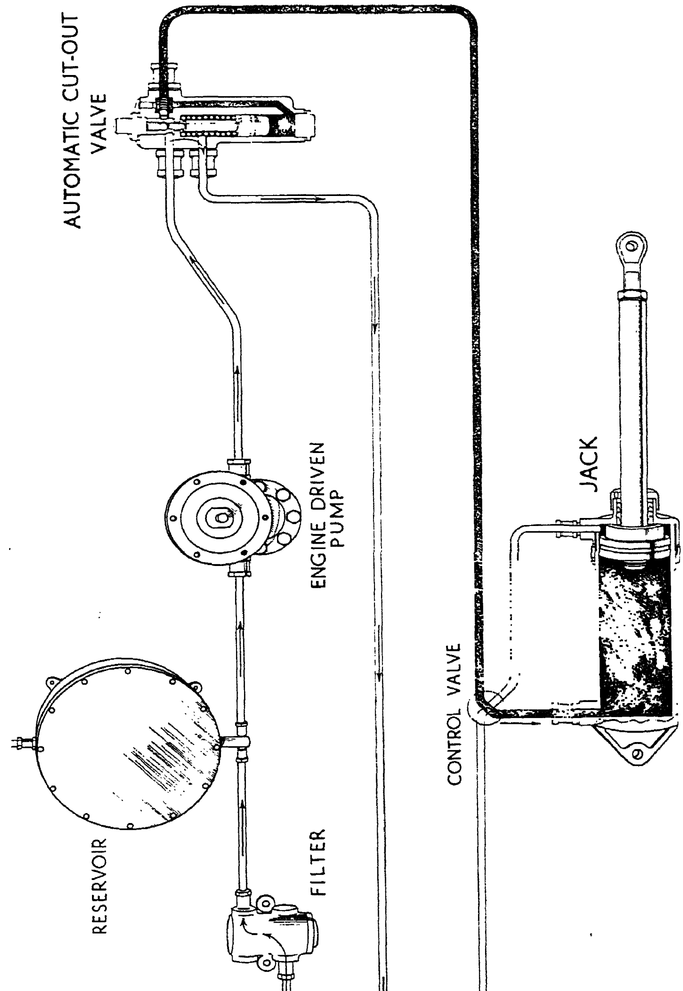


Fig. 26. Conditions in Automatic Cut-out Valve at end of Piston Travel

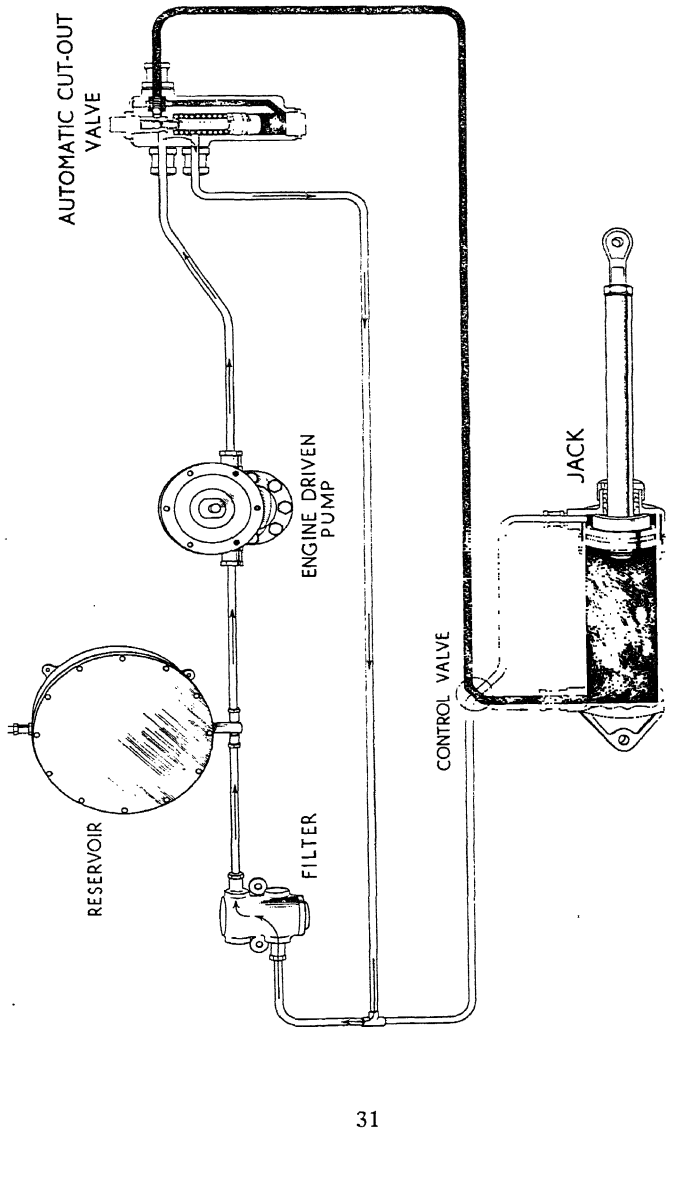


Fig. 26. Conditions in Automatic Cut-out Valve at end of Piston Travel

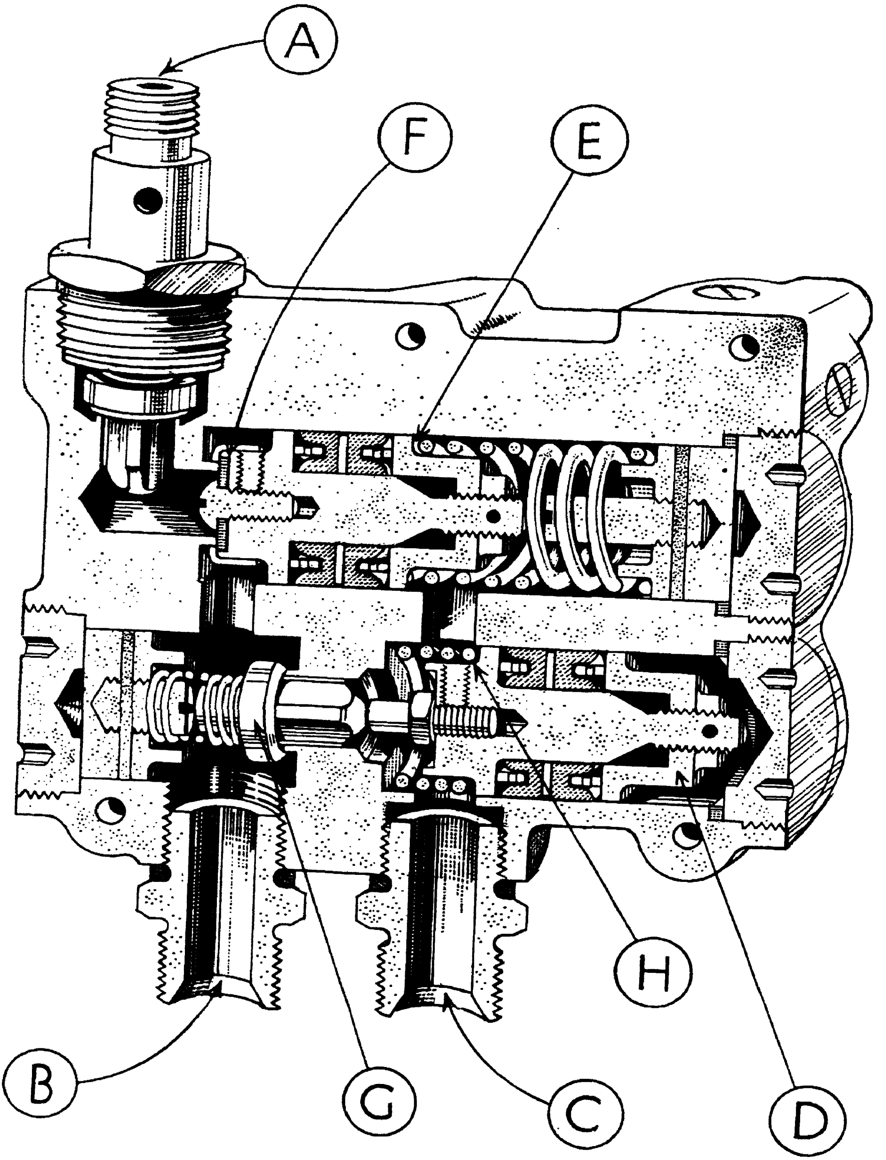


Fig. 27. Automatic Short Circuiting Valve

CHAPTER V

AUTOMATIC SHORT CIRCUITING VALVE

WHEN released from the retracted or " up " position, practically all hydraulically operated undercarriages fall under gravity through a considerable portion of their travel to the extended or " down " position.

With sideways retraction the wheels fall to within a few degrees of the landing position, but with rearward retraction their fall is limited by air drag. However, they complete approximately three-quarters of their travel without the aid of extending means, and the time taken for this fall is in the order of one second.

When the undercarriage control is moved into the " down " position, and the pump commences to deliver oil to lower the undercarriage, the " up " locks (if fitted) will be released and then, when the undercarriage falls under its own weight, the oil on the underside of the jack pistons will be swept back to reservoir and a partial vacuum created in the upper end of the cylinders.

In all probability the engine pump is now running slowly as the aircraft engine is partly throttled back. There will be a considerable time lag before the pump delivers sufficient oil to fill the empty jack cylinders. On one large aircraft this time lag was found to be approximately 1½ minutes.

To reduce the time of undercarriage extension, the valve illustrated in Fig. 27 has been evolved. To understand the operation of this valve it is necessary to appreciate the functions it must perform. Commencing with the undercarriage in the " up " position :

(a) When the control valve is set to the " down " position, oil must be fed from the pump to the upper end of the jack cylinders to release the " up " locks (if these are provided) and at the same time the pipe line from the lower end of the cylinders must be coupled to the reservoir.

(b) Immediately the undercarriage commences to fall under gravity, the return connection to the reservoir must be closed and oil from the underside of the piston led back to the top end of the cylinder. This condition must be maintained during the free fall of the undercarriage.

(c) When the undercarriage ceases to fall under its own weight, the pipe connecting the lower end of cylinder to the upper end must be closed and the lower connection must again be opened to reservoir.

These requirements are rendered difficult as the underside of the piston is subjected to heavy oil pressure under two entirely different conditions necessitating correspondingly different valve reactions. During the free fall a heavy oil pressure is built up in the lower end of the cylinder and under these conditions oil swept out should be returned to the upper portion of the cylinder, whereas, during retraction, oil is fed to the lower end of the cylinder and must not be allowed to by-pass to the upper portion.

Examination of the section of the valve shown in Fig. 27 will reveal how these requirements have been met.

Connection (A) is coupled to the main pipe from the pump to the upper end of the undercarriage jack.

Connection (B) is coupled to the lower end of the jack, and pipe line from connection (C) returns to the reservoir. There is a communicating oil passage between connection (A) and the space behind piston (D), and similarly there is a communication between connection (C) and the back of piston (E).

Passage (A) to (D) is drilled in the valve body but has been omitted from this drawing for clarity.

The sequence of events during extension of the undercarriage is as follows: Oil under pressure is fed from the pump to the upper end of the cylinder and this pressure acts on piston (D), causing it to move forward and lift valve (G) from its seat, thus opening up an oil way from connection (B) to connection (C) and allowing oil from the lower end of the cylinder to return to the reservoir.

When the undercarriage commences to fall under gravity a partial vacuum is formed in the upper end of the cylinder, and this relieves the oil pressure behind the piston (D) which returns to its original position under the influence of spring (H). Consequently, the valve reseats itself and the return circuit to reservoir is thereby closed. Under these conditions oil swept out from the lower end of the undercarriage jacks forces piston (E) along its cylinder and this carries the valve, thereby allowing the oil to escape through connection (A) back to the upper end of the undercarriage jack. This condition is maintained until the undercarriage ceases to fall, and as oil is still being supplied from the pump the valves and pistons in the short circuit valve revert to their original positions and allow the pump to complete extension of the undercarriage.

Different conditions arise when the undercarriage is being retracted. Connection (A) is communicating with what has now become the return pipe to the reservoir, and connection (C) is receiving oil from the pump. Pressure is reacting on the piston (E) and thereby holding valve (F) on to its seat. At the same time valve (G) is lifted off its seat and oil from the pump is delivered to the underside of the jack to effect retraction of the undercarriage.

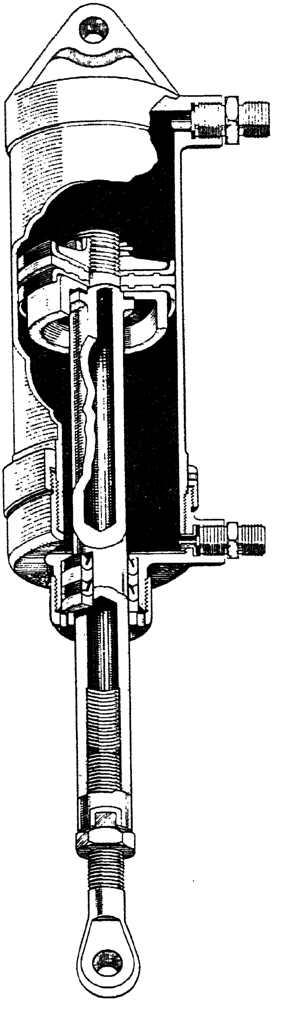


Fig. 28
Construction of Typical Jack

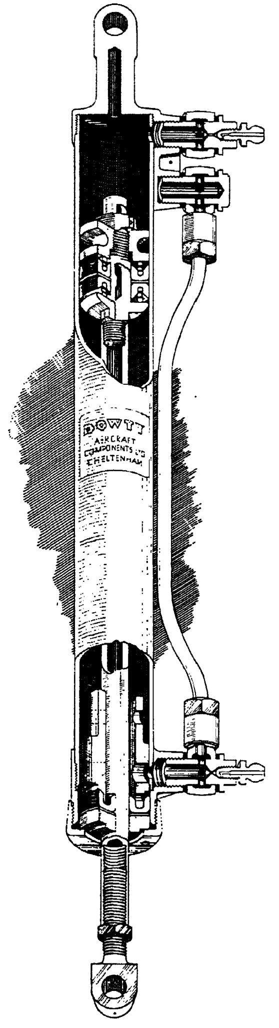
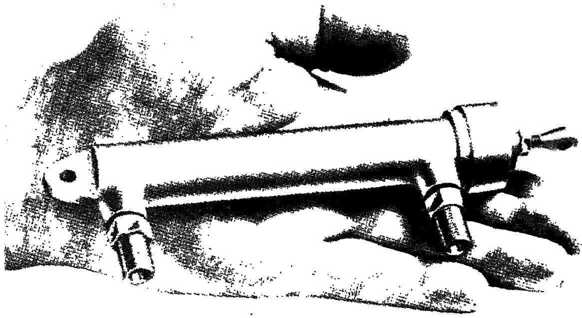


Fig. 29
Jack incorporating Bleeder Valves

CHAPTER VI

JACKS

HYDRAULIC jacks are made in a wide range of forms and sizes, varying from undercarriage jacks, 6 ft. or 7 ft. long, to small units for operating fuel cocks and similar auxiliary controls.



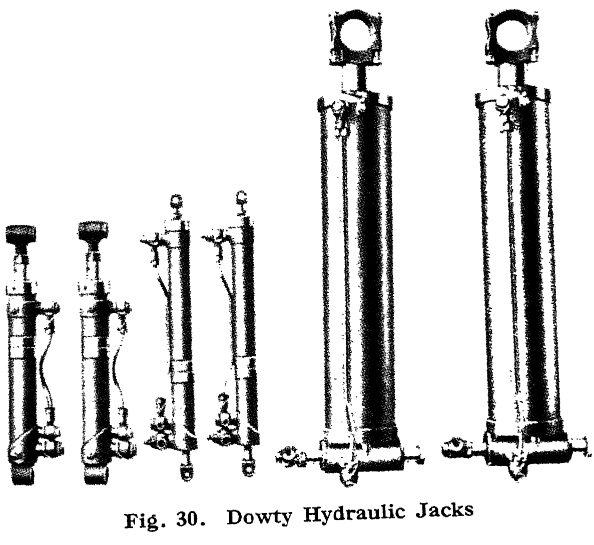


Fig. 30. Dowty Hydraulic Jacks

Fig. 30 shows a range of jacks and gives some idea of the forms in which these are made.

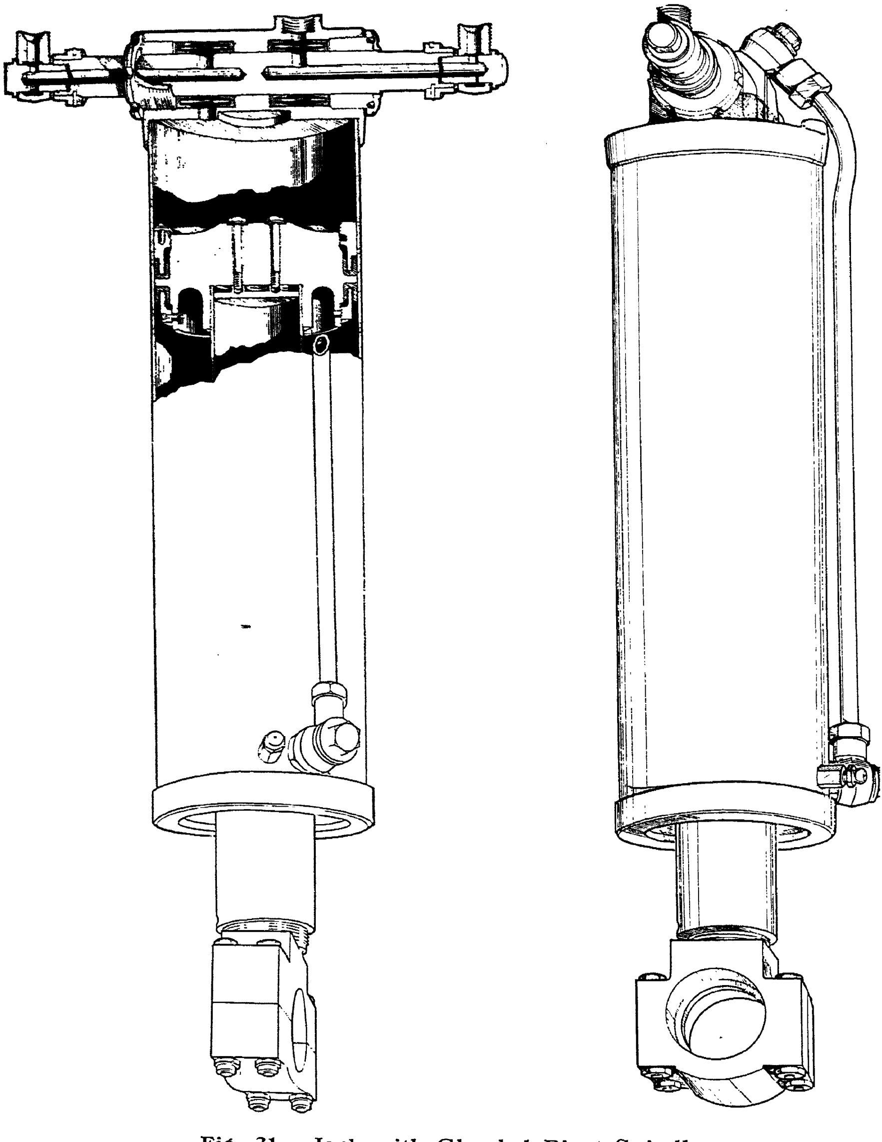


Fig. 31. Jack with Glanded Pivot Spindle

Fig. 28 illustrates a section through a typical jack. The cylinder barrel is machined from a steel or light alloy forging and the piston rod is plated with hard chromium to resist corrosion and wear. The piston rings and gland rings are of synthetic rubber which is impervious to the action of oil. Adjustment is provided at the eye end of the piston rod to vary the pin centre length of the jack.

A jack incorporating bleeder valves is shown in Fig. 29. These bleeder valves provide a means of removing all air from the jacks after installation on the aircraft and pipe lines have been coupled up. Another form of jack is illustrated in Fig. 31. This unit permits the use of rigid pipe lines, although any desired angular movement of the jack may take place during the piston travel.

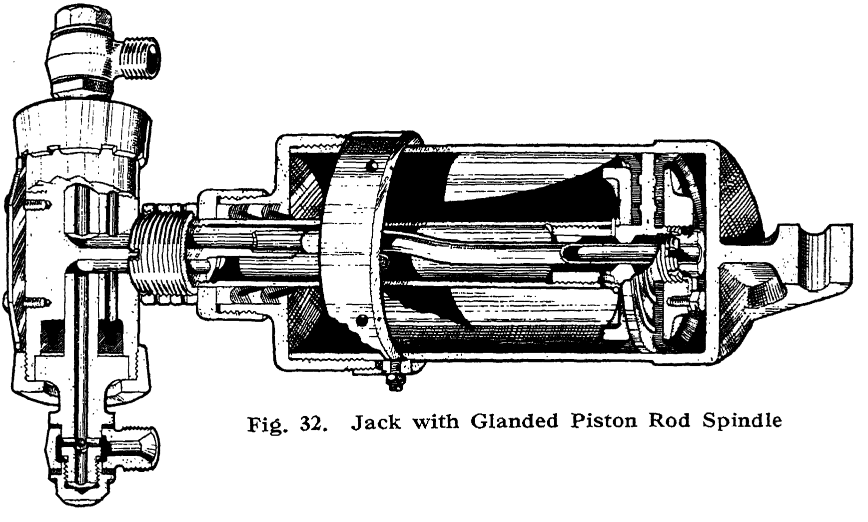


Fig. 32. Jack with Glanded Piston Rod Spindle

The main pivot spindle (on which the jack rotates) is provided with glands and oil passages through the pivot pin, which communicate with corresponding oil ways in the jack cylinder head.

The oil pipes from the control valve are coupled directly to the ends of the pivot pin, and one oil way communicates with the cylinder above the piston, while the other opens to a pipe passing along the outside of the jack to the underside of the piston.

A further variation of this type of jack is illustrated in Fig. 32 in which it will be seen that the oil pipes pass through the piston rod. The pivoted end of the piston rod is provided with glanded oil passages similar to those mentioned in the description of the previous jack.

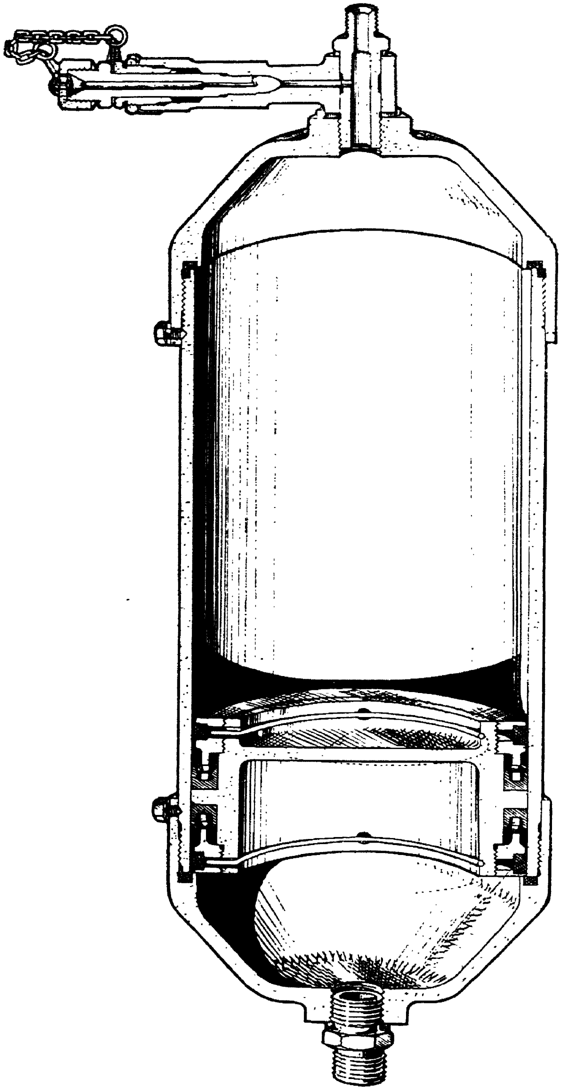


Fig. 33. Hydraulic Accumulator

CHAPTER VII

HYDRAULIC ACCUMULATORS

FIG. 33 shows a section of a simple accumulator as used for wheel brake operation and, in some systems, for flap circuits.

When small flap jacks are employed, in conjunction with a high delivery engine driven pump, the operation of the flaps will be too rapid unless the oil flow is restricted.

If a restriction valve is fitted between the pump and the jacks, high pressures are built up in the pipe lines, with the result that the automatic cut-out valve cuts off the supply ; a small quantity of oil then creeps through the restriction valve, causing a drop in pressure, and the cut-out again opens up the pump supply. This alternation recurs very rapidly, causing hammering in the cut-out and pipe line. To overcome this an accumulator is placed between the cut-out and the flap jacks to operate the jacks throughout their entire travel, so avoiding the necessity of the cut-out operating during this period.

The accumulator consists of a body with the ends sealed by means of screwed caps and sealing washers. An inflation valve is provided at one end and a floating piston separates the air and oil chambers.

The functioning of these accumulators has already been described.

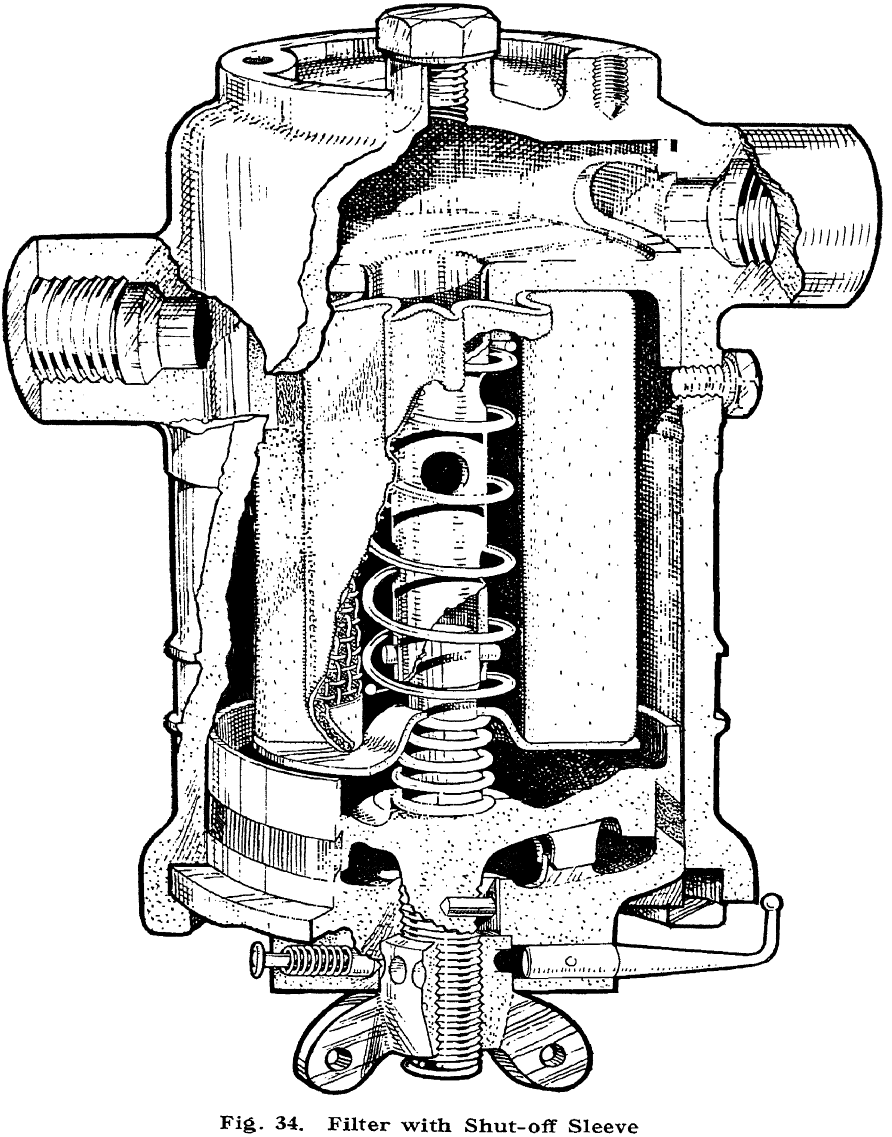


Fig. 34. Filter with Shut-off Sleeve

CHAPTER VIII
FILTERS

FILTERS prevent foreign matter circulating continuously through the hydraulic system.

Fig. 34 illustrates a filter designed to prevent loss of oil when the unit is dismantled for cleaning.

A sleeve inside the filter has openings corresponding with the pipe connections. When the base is removed this sleeve is automatically rotated to close off the ports.

As the pipe lines cannot admit air during the cleaning process, bleeding is unnecessary. The filter is refilled with oil after assembly by removing a plug in the dome of the body.

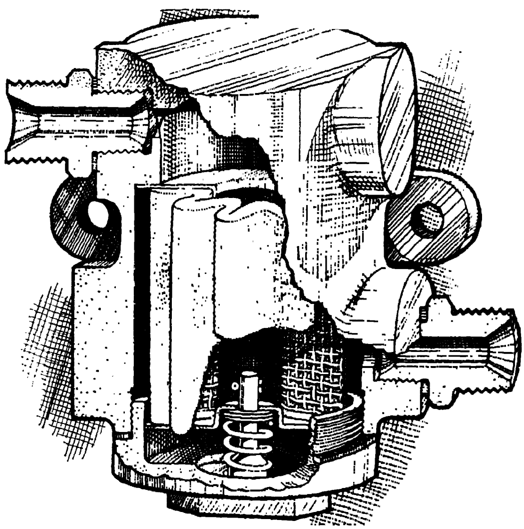


Fig. 35. Small Type Filter

The filter element consists of a corrugated felt tube reinforced internally by a woven wire mesh. Oil passes from the outside of the felt tube to the inside and then through the centre tube to the outlet connection.

A smaller type of filter commonly used on hand pump installations is shown in Fig. 35. This consists of a light alloy body with a removable base and a filter element of corrugated felt reinforced by a woven wire mesh.

In both the units described a coil spring in the centre of the tube prevents collapse of the filter element under pressure.

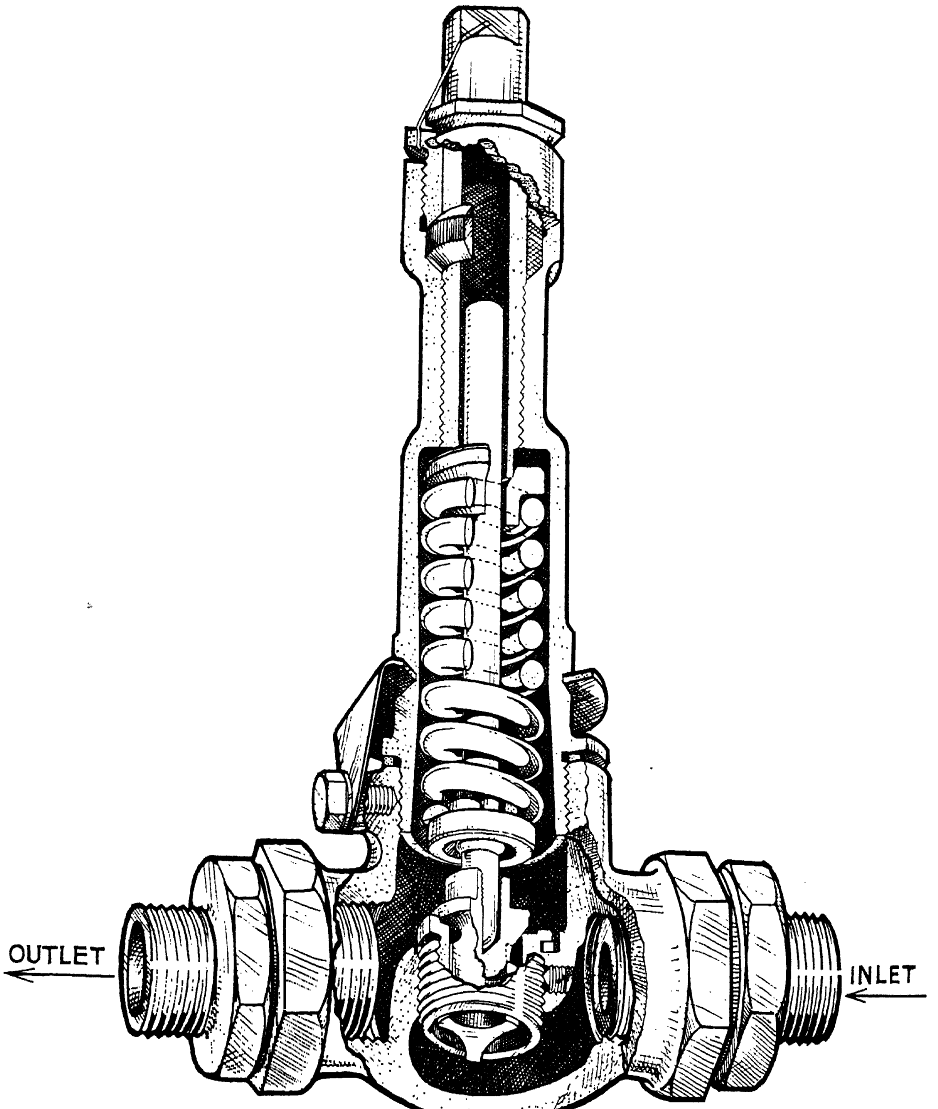


Fig. 36. Pressure Relief Valve

CHAPTER IX

RELIEF VALVES

RELIEF valves are incorporated in hydraulic installations for three reasons:

1. To provide a safety device should an automatic cut-out valve fail.
2. To enable trailing edge flaps to blow up at some predetermined air load.
3. To prevent excessively high pressures building up in a closed circuit due to a rise in oil temperature.

To meet the first requirements, the valve must be of generous proportions so that it can pass the full engine pump delivery without excessive heating of the oil. Such a valve is illustrated in Fig. 36. The relief valve takes the form of a cone surfaced plunger sitting on a knife edged seating. Pressure is applied by means of a spring, the initial compression of which is adjustable to give the desired blow-off figure.

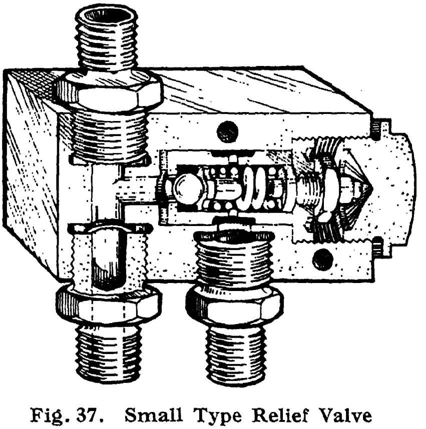


Fig. 37. Small Type Relief Valve

Valves to meet requirement (2) can be of smaller proportions as they do not deal with such large volumes of oil. Fig. 37 illustrates a relief valve of this type usually connected to the pressure and delivery lines between the control valve and the jacks.

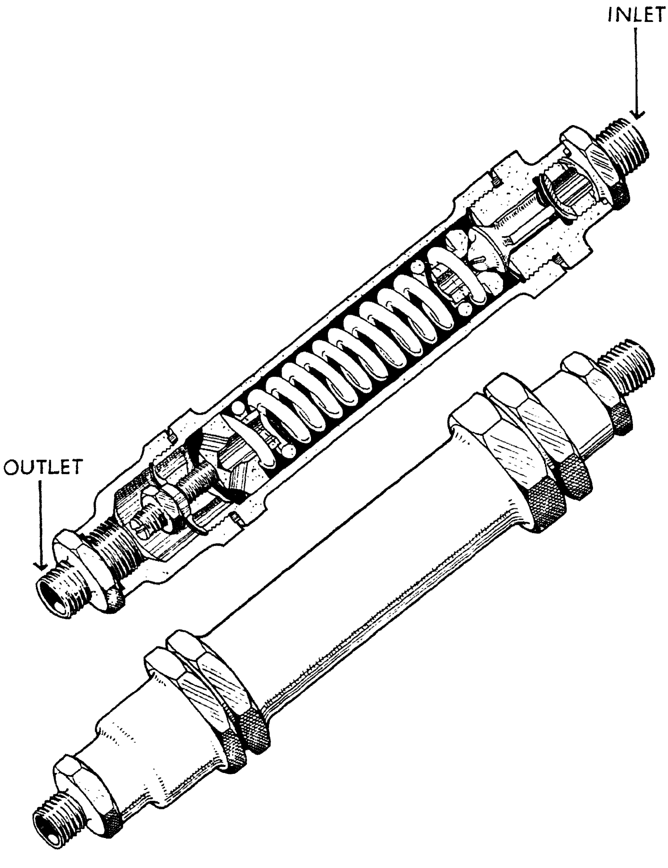


Fig. 38. Tubular Type Relief Valve

Fig. 38 shows an alternative form of relief valve. In both types the blow-off pressure is regulated by spring adjustment.

If the jacks are operated immediately after starting the engine or with the aircraft flying at high altitude then, after the cut-out has functioned or the 'Live'-Line pump has cut off the oil supply, the pressure pipe line constitutes a closed circuit containing a volume of cool oil.

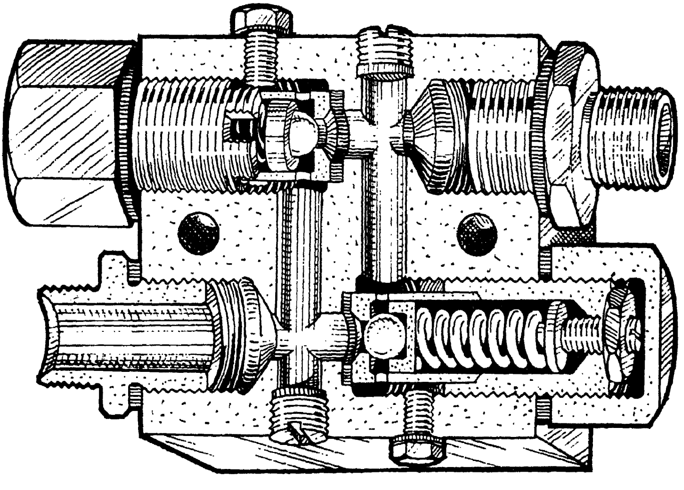


Fig. 39. Double Acting Relief Valve

If the aircraft then flies into a warmer atmosphere, or if the pressure line is adjacent to the engine, a rise of temperature will take place causing excessively high pressures in the system unless a relief valve is provided. As the pipe lines between the control valve and the jacks become alternately feed and return lines (according to which way the jack is operated) it is necessary to provide a double-acting valve of the type shown in Fig. 39 to meet requirement (3).

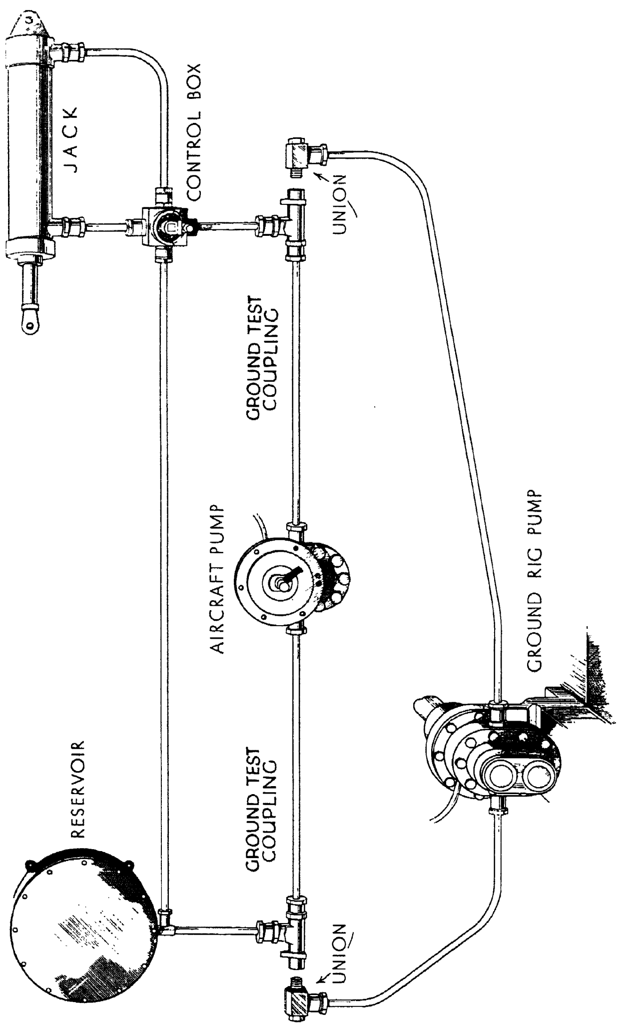


Fig. 40. Installation of Ground Test Couplings

CHAPTER X

GROUND TEST COUPLINGS

WHEN it is necessary to test the functioning of retracting undercarriages before flight it is usual to carry out these tests by coupling the pipe lines to a ground test pump driven by an electric motor or petrol engine.

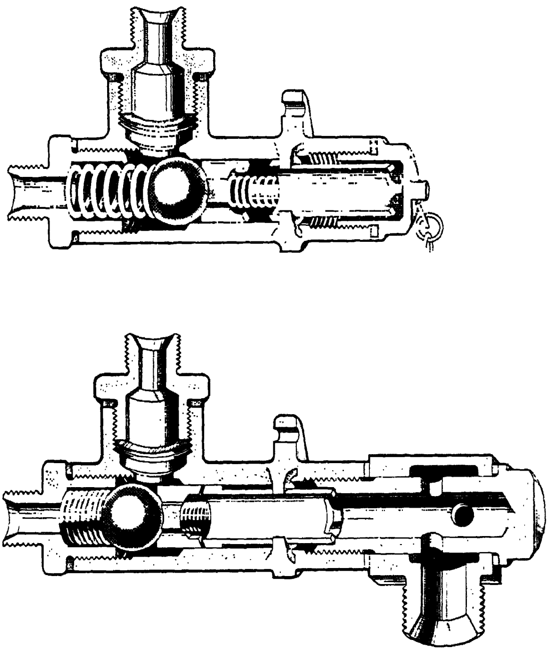


Fig. 41. Sections through Ground Test Couplings

This can be achieved without breaking pipe lines in a normal circuit by using Dowty ground test couplings which are fitted in the main feed and return lines. These couplings are provided with balls which normally seat so that the union with the external pipe connection is closed off and the flow through the pipe is not affected. When the external pipe line from the ground test pump is coupled on, the balls are forced off their seats to permit flow to and from the ground test pump and at the same time the pipe lines from the aircraft engine-driven pump are closed off.

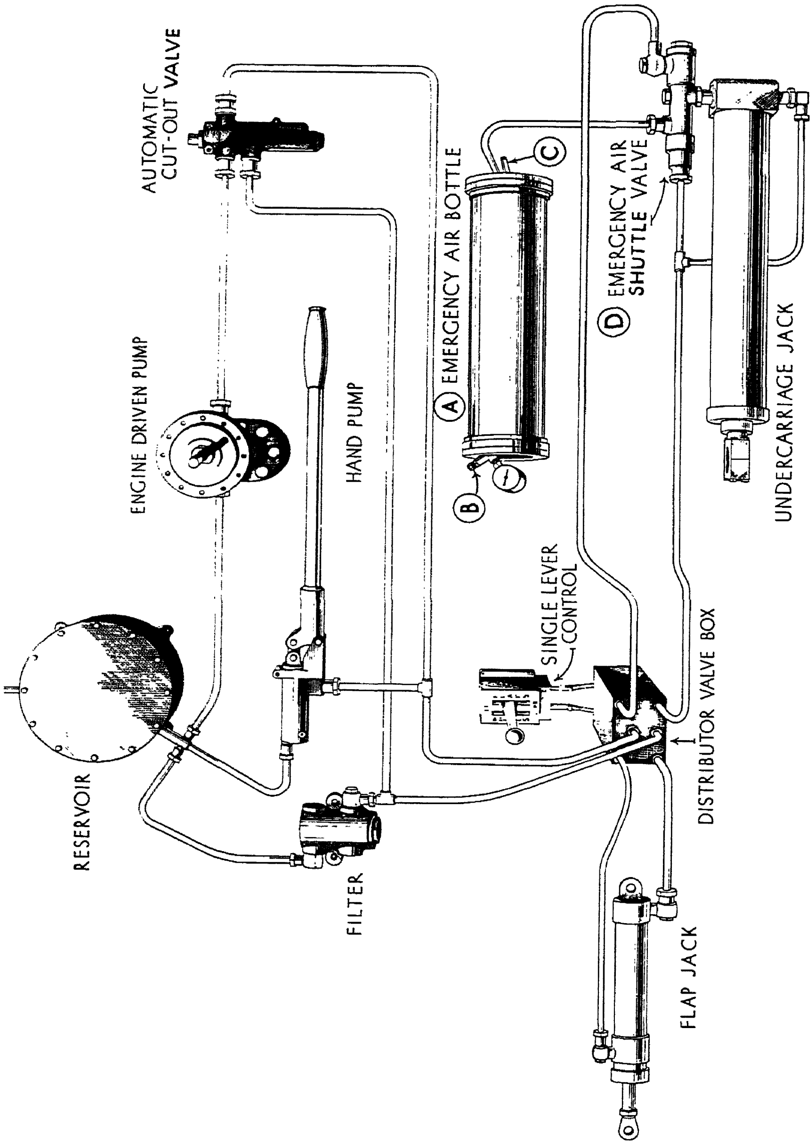


Fig. 42. Hydraulic System with Emergency Air Extension

CHAPTER XI

SAFETY DEVICES

TO guard against failures in the hydraulic and retraction systems various safety devices are now used and amongst these may be mentioned:

1. Emergency extension devices which permit undercarriage lowering should the normal extending means fail.
2. Locks to secure the undercarriage in the extended position.
3. Warning devices to prevent the pilot landing with the undercarriage up.

Dealing first with emergency extending devices, hydraulic actuation lends itself readily to an auxiliary form of extension. This consists of compressed air stored in a cylinder which is provided with an inflation valve and pressure gauge. When air is released from the cylinder it flows to the jacks, thus extending the undercarriage.

Fig. 42 shows a diagram in which the various units for air emergency extension are featured.

The bottle (A) is inflated through valve (B) by means of a compressor of the type used for inflating pneumatic shock absorber struts. This is a ground operation which is independent of any air compressor on the aero engine, consequently engine failure does not render this emergency device inoperative.

To operate the emergency extension system lever (C) is pulled, and this opens a valve to release the air to the undercarriage jacks. A typical storage bottle is illustrated in Fig. 43.

Fig. 44 shows the air supply valve. This incorporates a slow leak device to prevent pressures building up in the air line due to leakage from the bottle into the valve body. When the release lever is actuated this leak is sealed and the full pressure from the bottle is then transmitted through the pipe line and emergency air shuttle valves into the jacks.

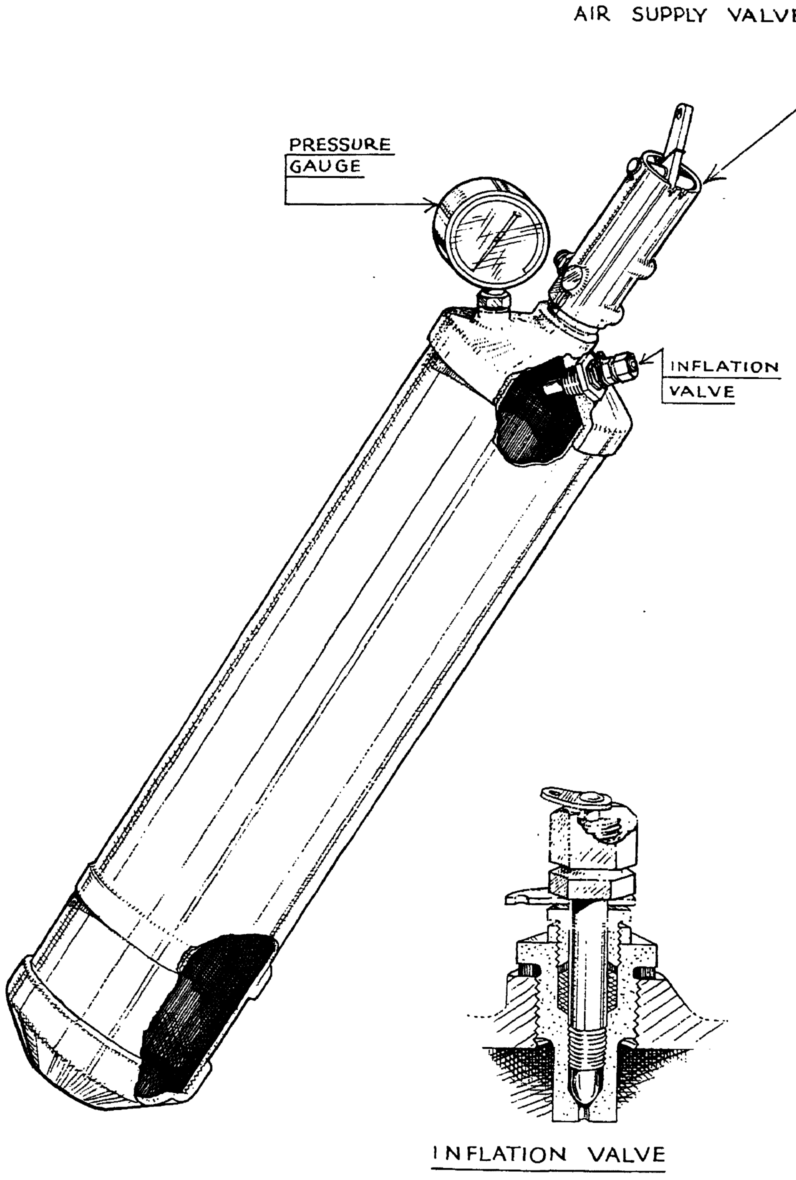


Fig. 43. Typical Air Storage Bottle for Emergency Undercarriage Lowering (Inset) Section through Inflation Valve

Air shuttle valves are mounted upon the undercarriage jacks, or in close proximity to them. Fig. 45 illustrates a typical unit. When the undercarriage is extended by compressed air means, the normal oil supply from the control box must be blanked off to prevent air escaping up this line and, simultaneously, a port must be opened to allow air to flow to the jack.

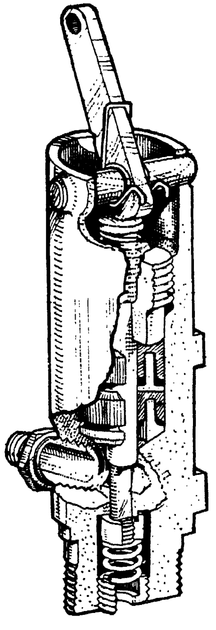


Fig. 44
Air Supply Valve

In addition, the return pipe line from the jack must be opened to atmosphere, thus permitting the jack piston to move.

During normal operation of the jack by hydraulic means, the oil supply from the pump is fed through connection (A) via passage (B) to the jack. Connection (C) is coupled to the air storage bottle and connection (D) is coupled to the opposite end of the jack. Connection (E) usually carries a short pipe communicating to atmosphere.

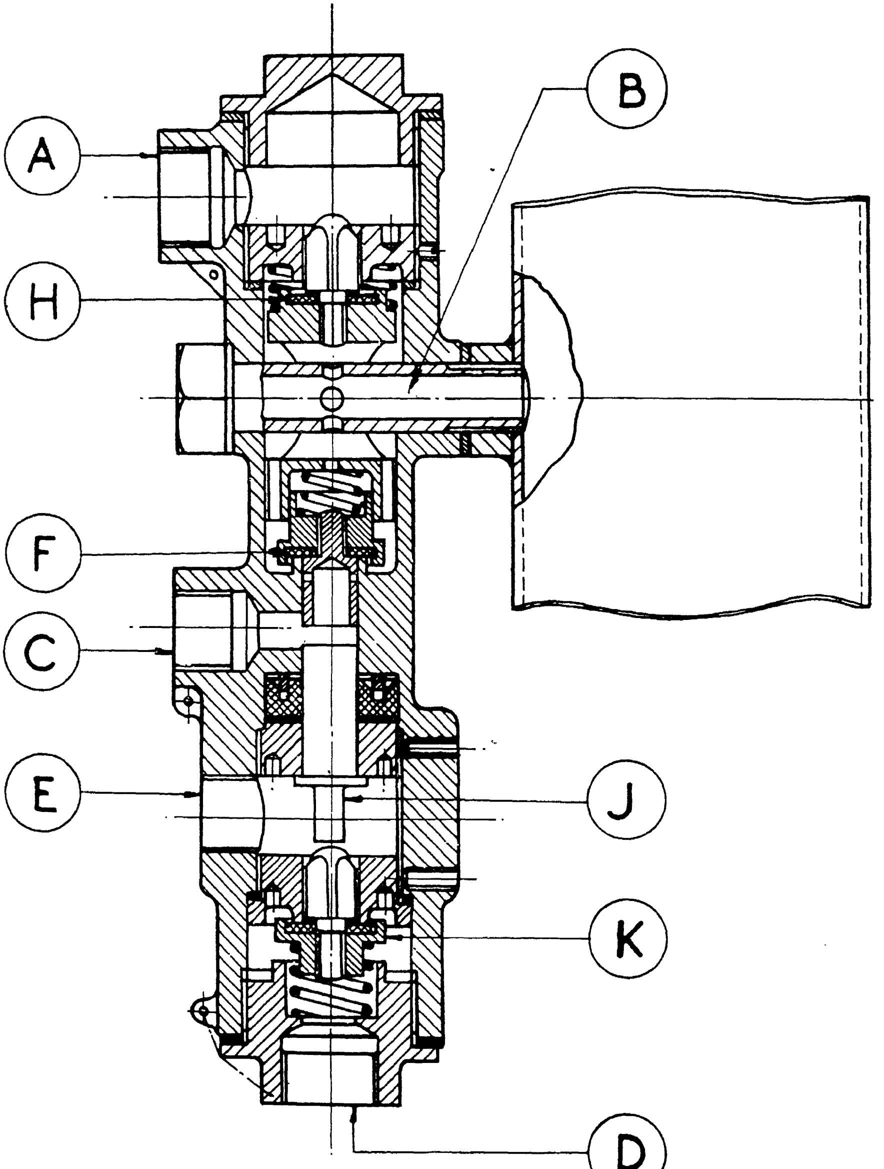


Fig. 45. Emergency Air Shuttle Valve

This valve is automatic in action. When compressed air is admitted through connection (C), valve (F) is forced off its seat, allowing air to pass through connection (B). At the same time valve (H) is held on its seat, thus preventing air from passing out through connection (A). Simultaneously, plunger (J) is forced along to lift valve (K) from its seat and allow oil from the lower side of the piston to escape into the atmosphere through connection (E).

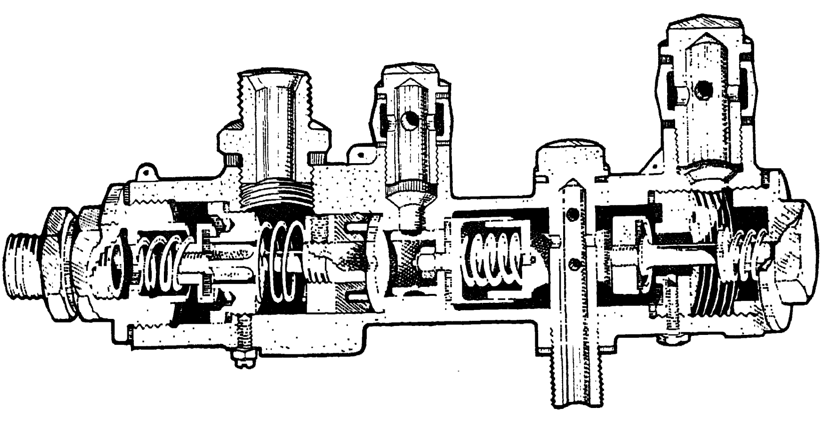


Fig. 46. Construction of Air Shuttle Valve

The construction of this valve is shown in Fig. 46.

Any number of jacks (for example, two undercarriage jacks and one tail wheel jack) may be operated from one air supply.

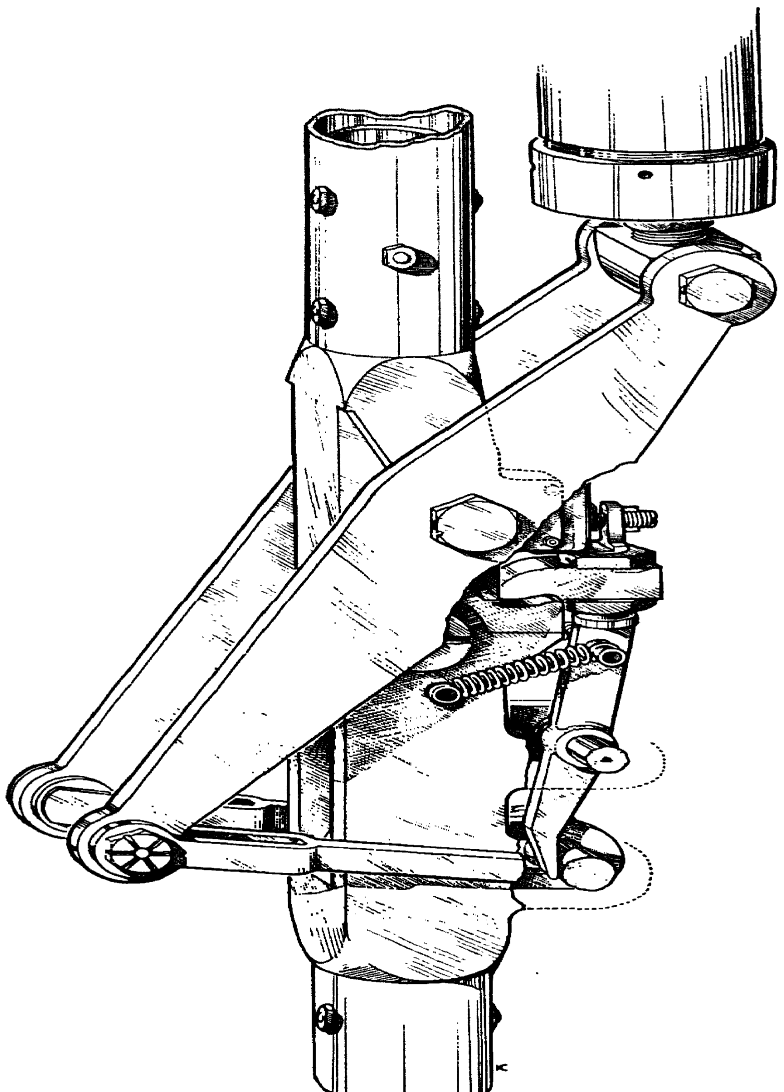


Fig. 47. Undercarriage Safety Lock

UNDERCARRIAGE LOCKS

The Air Ministry requires all service aircraft to be fitted with locks to secure the undercarriage in the extended position. It is now general practice to provide similar locks to retain the undercarriage in the retracted position. When hydraulic actuation is employed it is a simple matter to operate the locks hydraulically and this can be effected by providing the retracting jack with a small amount of free travel at the commencement of the " up " and " down " strokes.

The down locks usually take the form of latches attached to one half of the breaking member and engaging with pins or projections on the other half, thus forming a definite tie between the two portions.

Similarly the up locks employ latch members attached to some part of the undercarriage and engaging with suitable pins rigidly anchored to the aircraft structure.

Normally these latches are held in engagement with their pins by springs in such a manner that when the pins move through their paths of travel (or the latches approach the pins), the cam shaped faces of the latches strike the pins and are forced back until the pins come into line with the latch slots, when the springs cause the latches to snap into position. The latches are released from engagement by the first part of the jack travel in either direction.

Fig. 47 illustrates one type of down lock. The link connecting the piston rod to one half of the breaking member of the undercarriage is provided with a pin engaging a slotted hole in the breaking member. The slot allows movement of the link through a portion of its travel before actuating the breaking member.

During this free travel the pin in the link is in contact with one end of a lever which extends beyond its fulcrum to form a latch which engages a projection on the other half of the member.

When the latch is in the locked position it actuates a switch which closes an electrical circuit to operate the indicator instrument.

Figs. 48 and 49 illustrate a knuckle joint for a retracting strut incorporating "up" and "down" locks, operated by free travel of the jack.

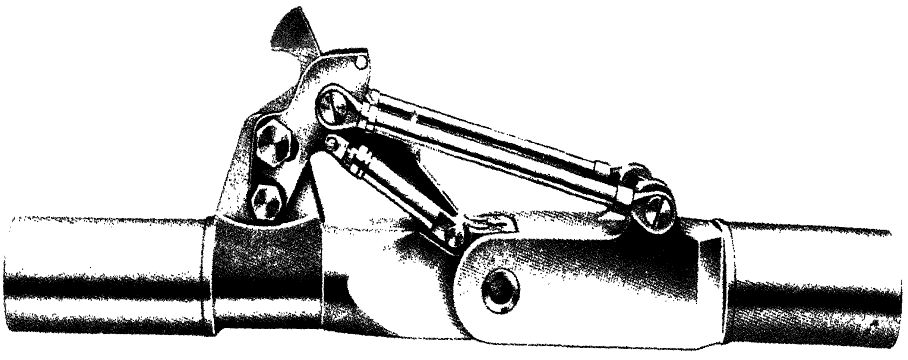


Fig. 48. Knuckle Joint with " Up " and " Down " Locks—Closed

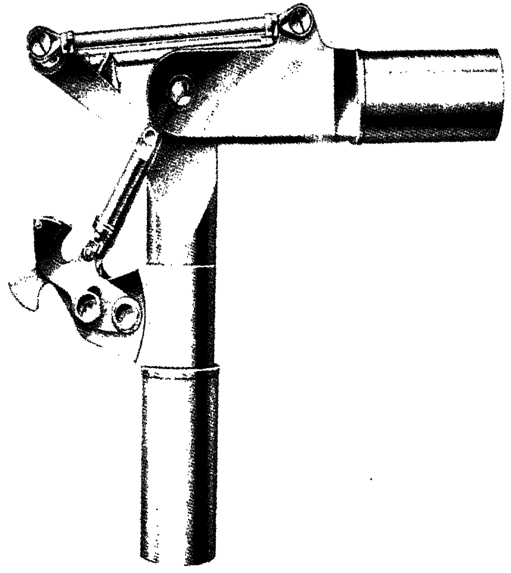


Fig. 49. Knuckle Joint with " Up " and " Down " Locks—Open

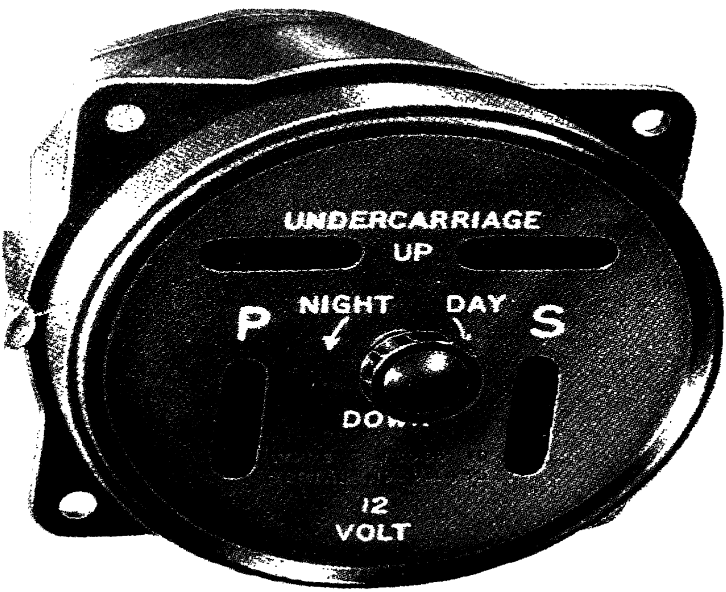


Fig. 50
Dowty Undercarriage Position Indicator Instrument

WARNING DEVICES

The safety devices so far described have been evolved to safeguard against mechanical failures, but there are others to assist the pilot.

Indication that the undercarriage is safely locked down before landing is provided by a dashboard instrument shown in Figs. 50 and 51.

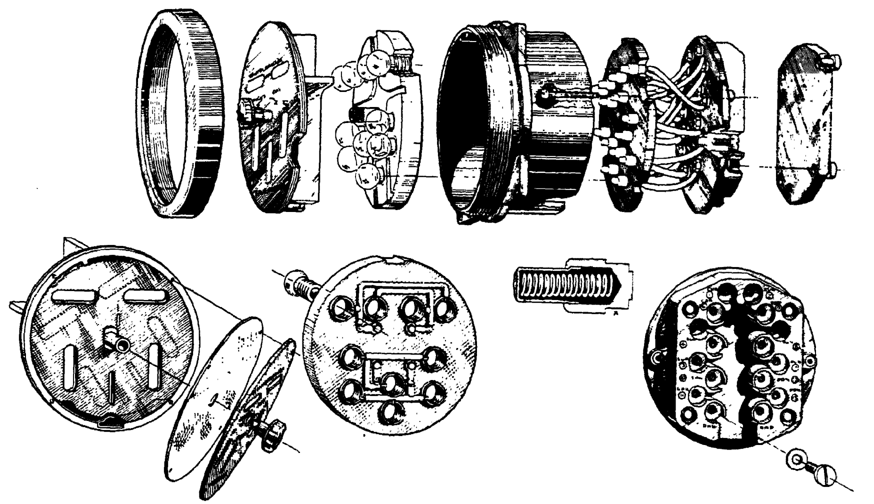


Fig. 51. Construction of Dowty Indicator Instrument

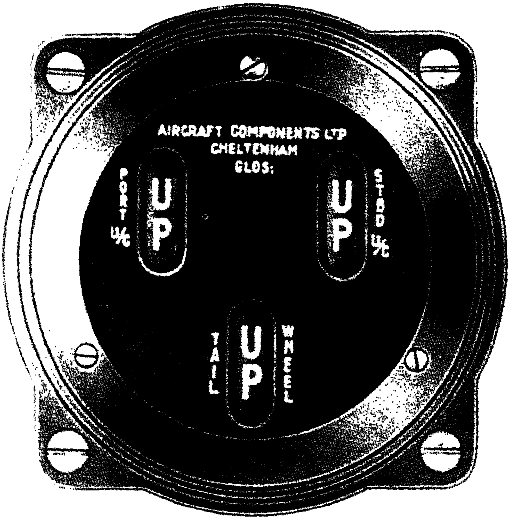
This is fitted with red and green signal lights to indicate that the undercarriage is either in the fully extended or fully retracted position. All these signal lights are fitted with twin bulbs on separate circuits.

A change-over switch is incorporated and in the event of failure of any one bulb, or any one set of bulbs, the pilot can bring the spare set of bulbs into action. A dimming screen is provided to reduce illumination intensity when required.

A type of indicator which does not rely on electric lamps is shown in Fig. 52. This overcomes the objection associated with signal lights that when flying during daylight hours in sunshine it is extremely difficult to see if the lamps are illuminated and, furthermore, when flying at night the lights are apt to dazzle the pilot.

This indicator incorporates flag type signals which are actuated by solenoids.

Wiring diagram for lamp type indicators is shown in Fig. 53.



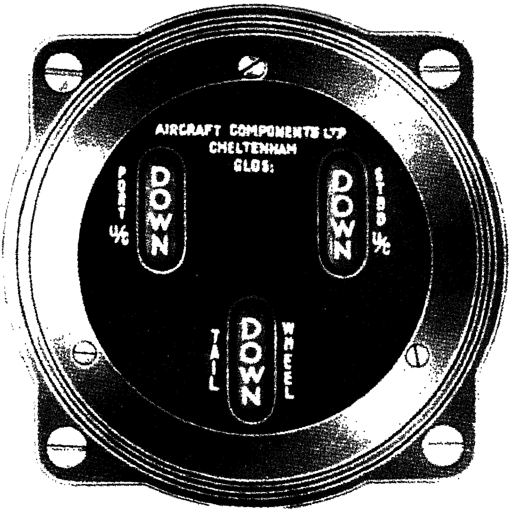


Fig. 52
Dowty Solenoid Type Indicator Instrument

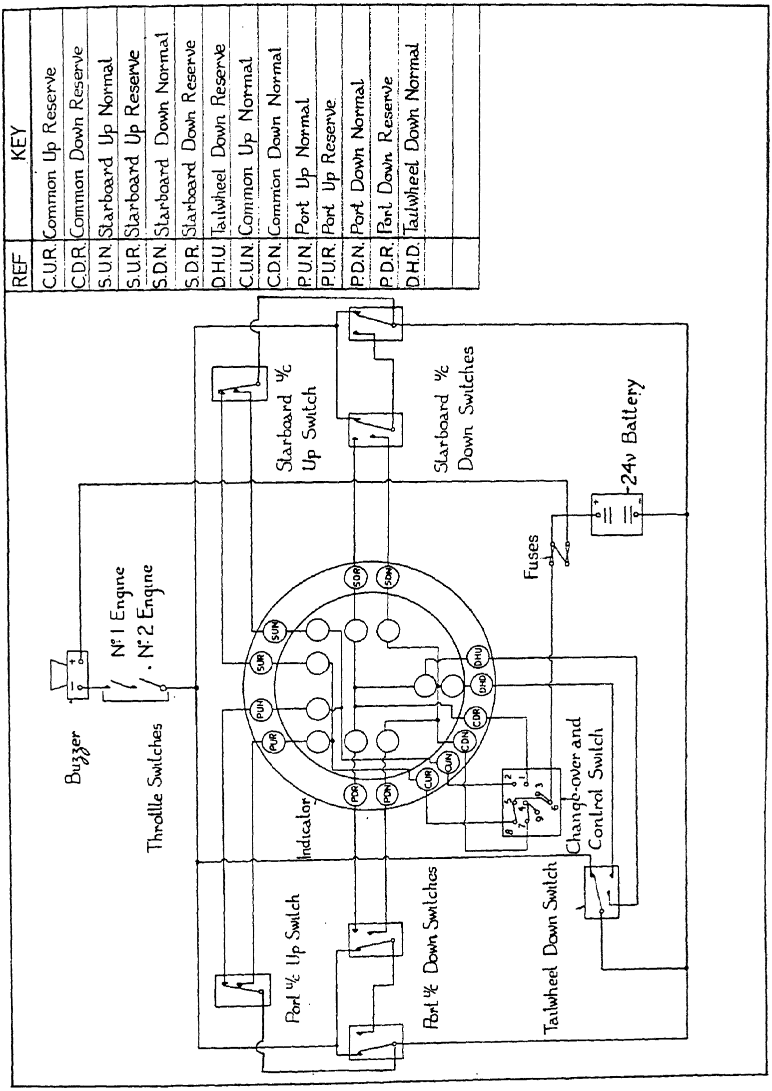


Fig. 53. Wiring Diagram for Lamp Type Indicator

Experience has proved that it is quite possible for the pilot to forget to lower his undercarriage before landing, and some form of warning device is required to prevent this occurrence.

This usually takes the form of an electric buzzer which is mounted close to the pilot's head. The actuating switch for this buzzer is interconnected with the throttle control so that if the pilot attempts to throttle back to less than one-third of the "open" position, the warning buzzer comes into operation unless the undercarriage is safely locked down. A typical buzzer is illustrated in Fig. 54.

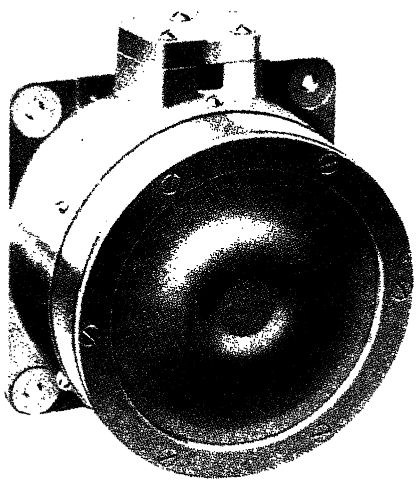


Fig. 54. Warning Buzzer

The power operation of retractable undercarriages introduces the possibility of inadvertent retraction by the inquisitive, or accidental working by the pilot, or again, by starting the engine with the undercarriage control in the "Wheels up" position. A safety device to prevent this possibility is illustrated in Fig. 55.

It consists of a spring loaded plunger locking the hand control unit so that the handle cannot be moved into the "Wheels up" position when the wheels are under load. The lower end of the plunger is connected by means of a cable to the moving member of the shock absorber strut and when the shock absorber is relieved of load (as the aircraft leaves the ground), the locking plunger is automatically withdrawn.

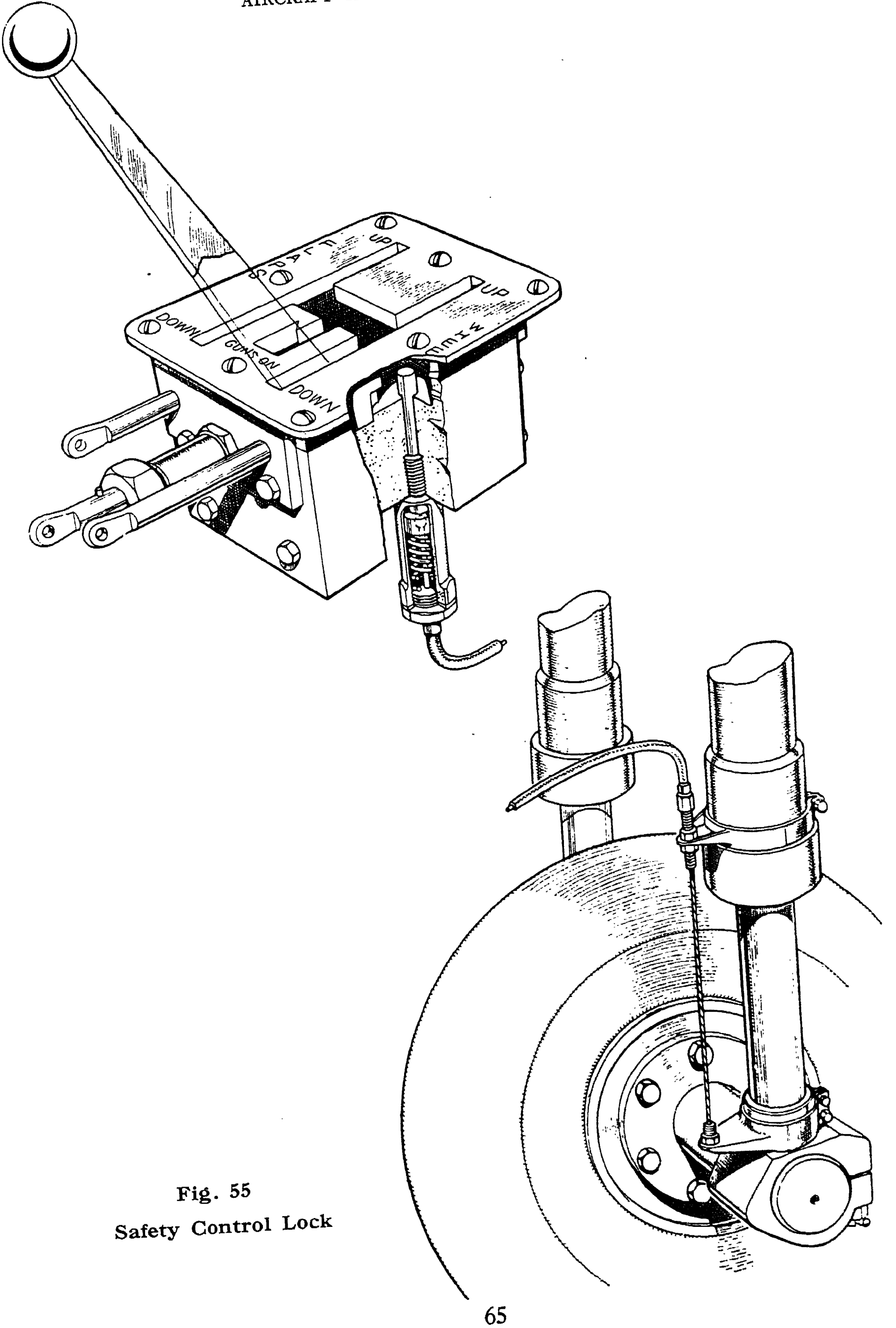


Fig. 55
Safety Control Lock

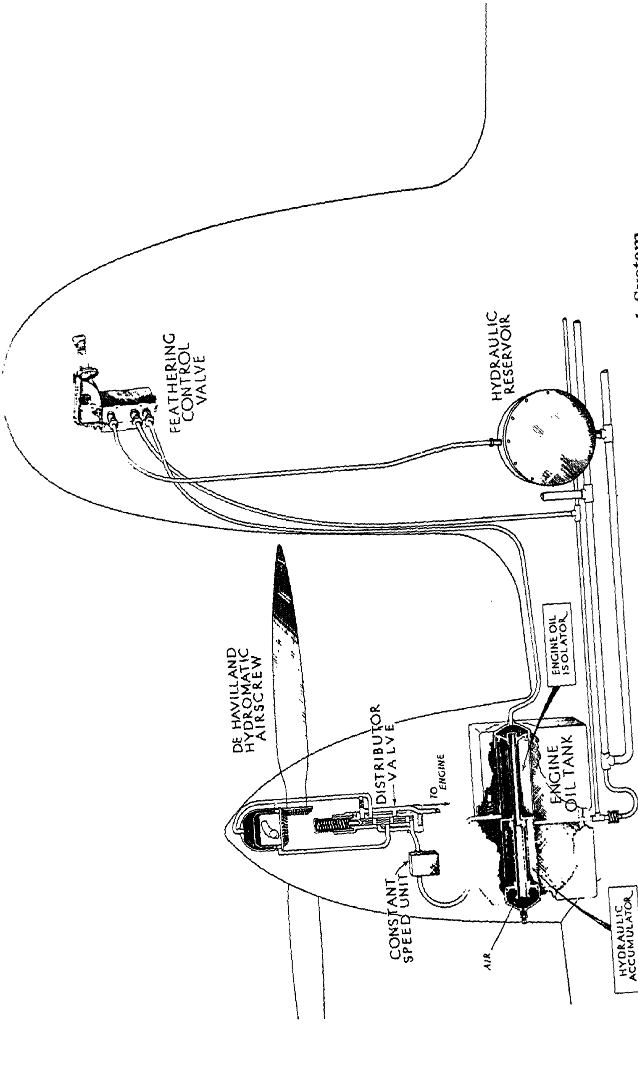


Fig. 56. Dowty Feathering Airscrew Control System

CHAPTER XII

FEATHERING AIRSCREW CONTROLS

FEATHERING airscrews can be actuated from the same power source as that operating the undercarriage, flaps, etc. This system shows considerable weight saving over the individual pumping installations in which an electric motor drives auxiliary pumps installed in each nacelle, oil for the pumps being drawn from the engine tank.

To control fully feathering airscrews, it is usual to employ hydraulic pressure, utilising the oil passages provided for constant speed control, but using considerably higher pressures.

When feathering and unfeathering, the higher pressures operate an automatic selector valve which blanks off the constant speed unit supply and feeds pressure direct to the airscrew hub.

Early systems operated from the normal hydraulic installation had one objectionable feature. The hydraulic fluid supplied to the airscrew hub in feathering was returned to the engine when unfeathering, thereby diluting the lubricating oil. When this dilution is permitted at all, the number of feathering operations must be limited by the degree of dilution permissible. To overcome this difficulty a system has been developed employing isolators which prevent the hydraulic fluid from entering the engine oil system but without affecting operation of the airscrews. This system is shown diagrammatically in Fig. 56.

A feathering control valve is mounted in the cockpit and pipes couple this valve to the hydraulic pressure system and the isolators. The valve is provided with a handle operating in a gate labelled "To feather" and "To unfeather." The pilot selects the desired position and on completion of the operation the handle returns to the neutral position. This valve is illustrated in Fig. 58.

The isolator is a single unit comprising three chambers, the first of which is a cylinder containing a floating piston. Hydraulic fluid is fed from the feathering control valve to one side of this piston.

The cylinder space on the opposite side of this piston is filled with engine oil and movement of the piston under hydraulic pressure ejects this oil to feather or unfeather the airscrews.

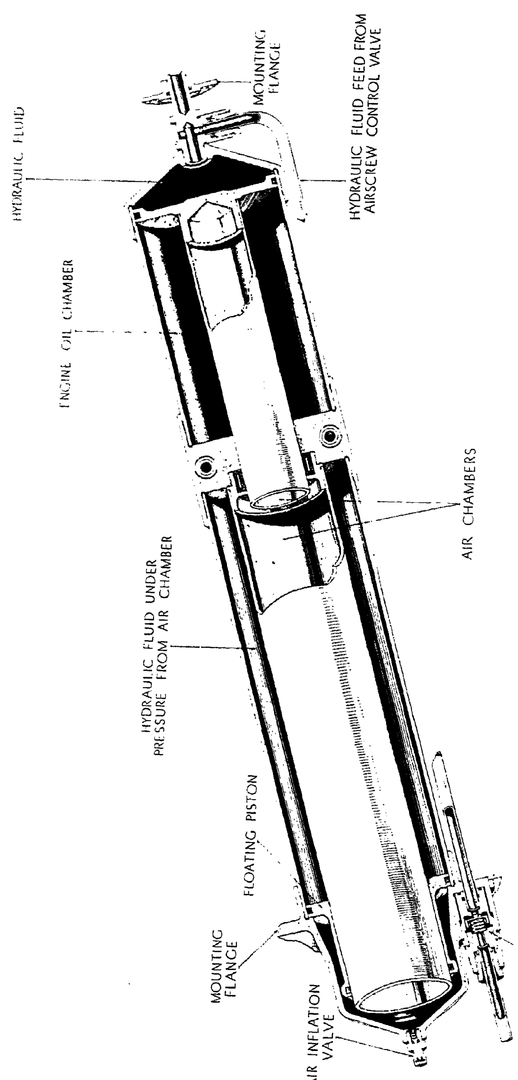


Fig. 57. Engine Oil and Hydraulic Fluid Isolator for Feathering Airscrew Control

The isolator also contains an air chamber which is inflated to a pre-determined pressure. When the feathering or unfeathering operation is completed and the control valve cuts off the hydraulic supply, air pressure forces the piston back, returning the hydraulic fluid to its reservoir, and sucking in another charge of engine oil through a non-return valve. Each operation takes a fresh supply of engine oil ready for the next operation.

This system is entirely automatic, self-indicating and its installation does not interfere with the functioning of the hydraulic circuit to which it is connected.

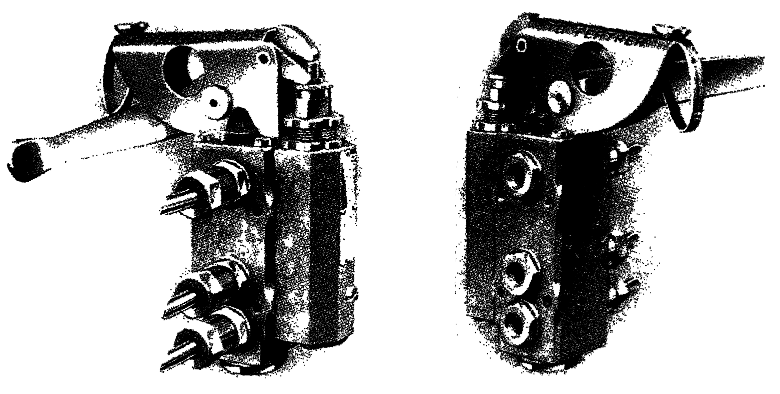


Fig. 58. Dowty Feathering Airscrew Control Valve

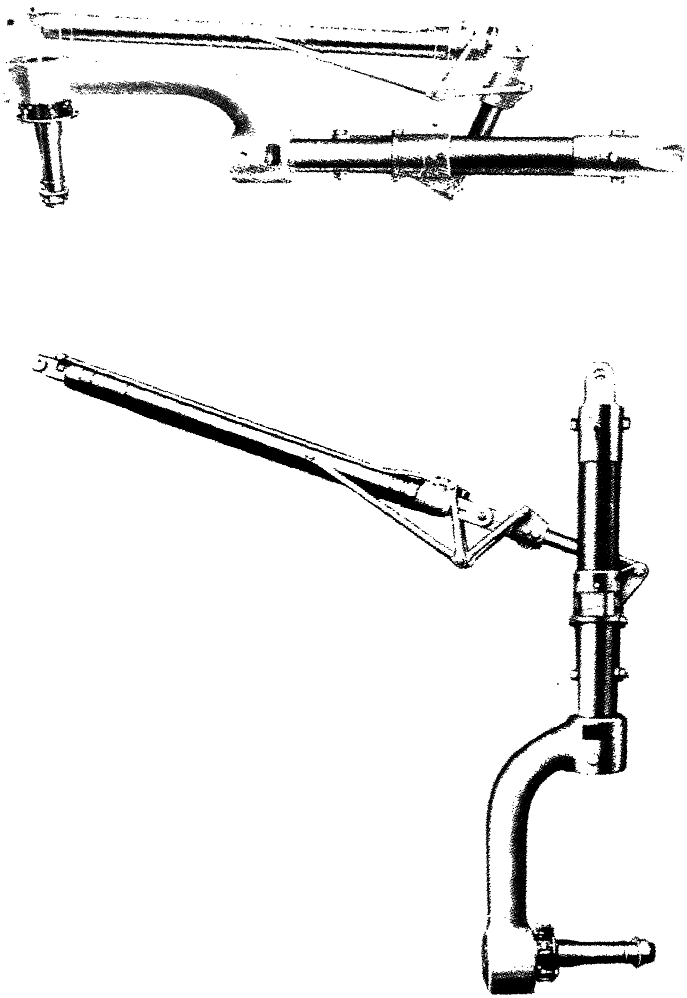


Fig. 59. Dowty Nutcracker Undercarriage

CHAPTER XIII

RETRACTING UNDERCARRIAGES

IT is beyond the scope of this book to describe the many designs of retracting undercarriages operated hydraulically but the lay-outs shown in this chapter illustrate typical installations.

An arrangement offering many advantages is shown in Fig. 59. This lay-out incorporates what are now generally known as nutcracker struts. The function of a strut of this type is to provide an undercarriage member which forms a rigid bracing for the compression leg when the undercarriage is extended, and also embodies a complete retracting mechanism (other than the source of power) in a self-contained unit.

The undercarriage illustrated in Fig. 59 is designed for sideways retraction and the nutcracker strut forms the side bracing member. The retracting jack is carried inside the upper tube of this folding strut and the retracting effort is transmitted from the jack through a simple arrangement of links to the lower half of the folding member.

An undercarriage for rearward retraction is illustrated in Fig. 60, and this incorporates another form of nutcracker strut in which the jack is a simple pin-jointed unit, anchored at its top end to a lug on the upper half of the folding member and at its lower end to a link pivoted near the hinge pin. The illustrations show the manner in which jack reaction provides the required angular movement and also operates latch locks to hold the undercarriage in the extended position. This arrangement was designed to cope with the unusual undercarriage attachment points provided on the aircraft structure. The nutcracker strut employed in this undercarriage is illustrated in Fig. 61.

Fig. 62 shows another rearward retracting undercarriage incorporating latch locks for both up and down positions; these locks are operated by free travel of the main retracting jack.

Fig. 63 illustrates a rearward retracting undercarriage actuated by a single jack attached to a lever forming an extension of the upper half of the folding member.

An undercarriage of extremely compact form is illustrated in Figs. 64 and 65.

In this design the compression legs and retracting struts fold within the very small space available in the leading edge of the wing.

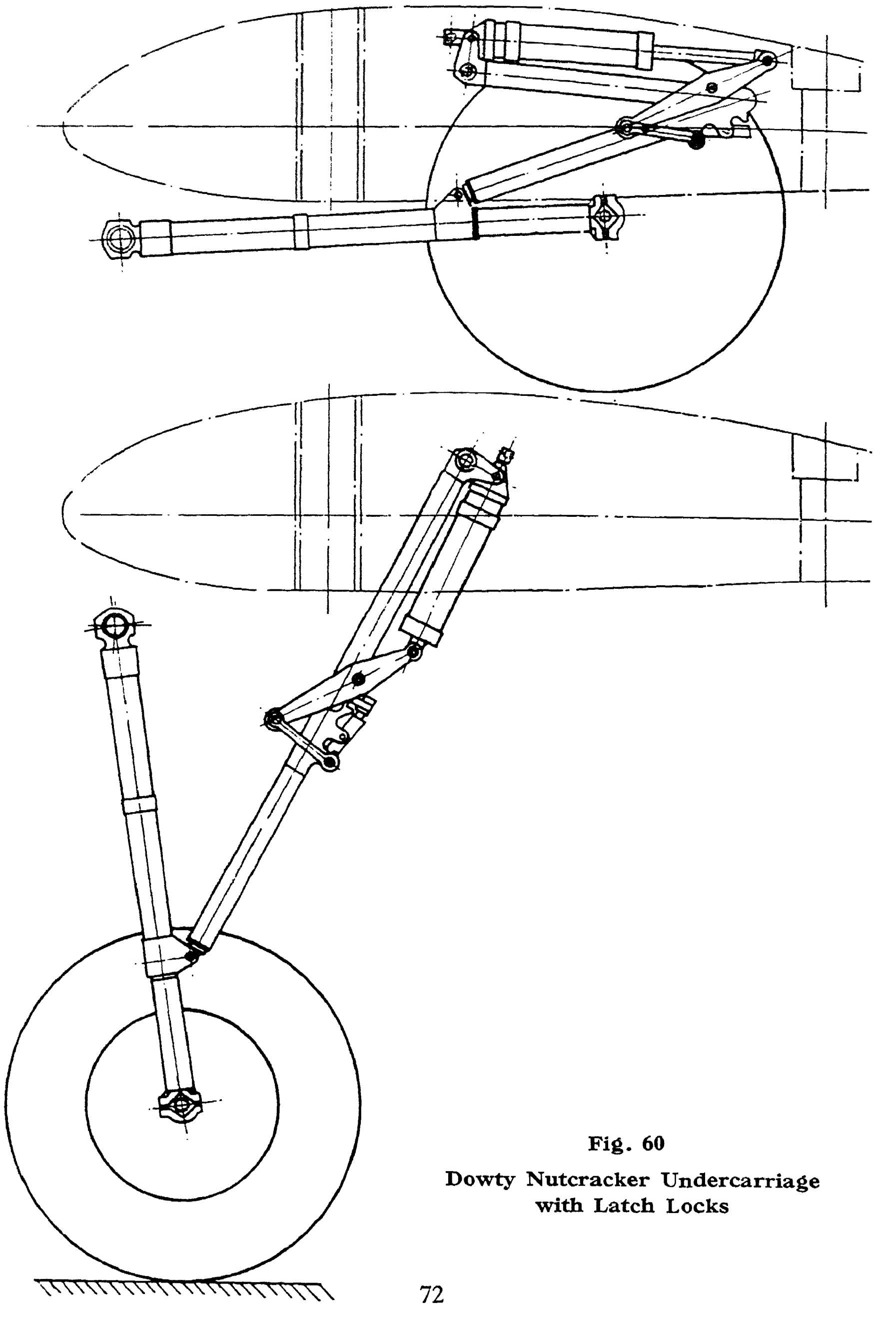


Fig. 60

Dowty Nutcracker Undercarriage with Latch Locks

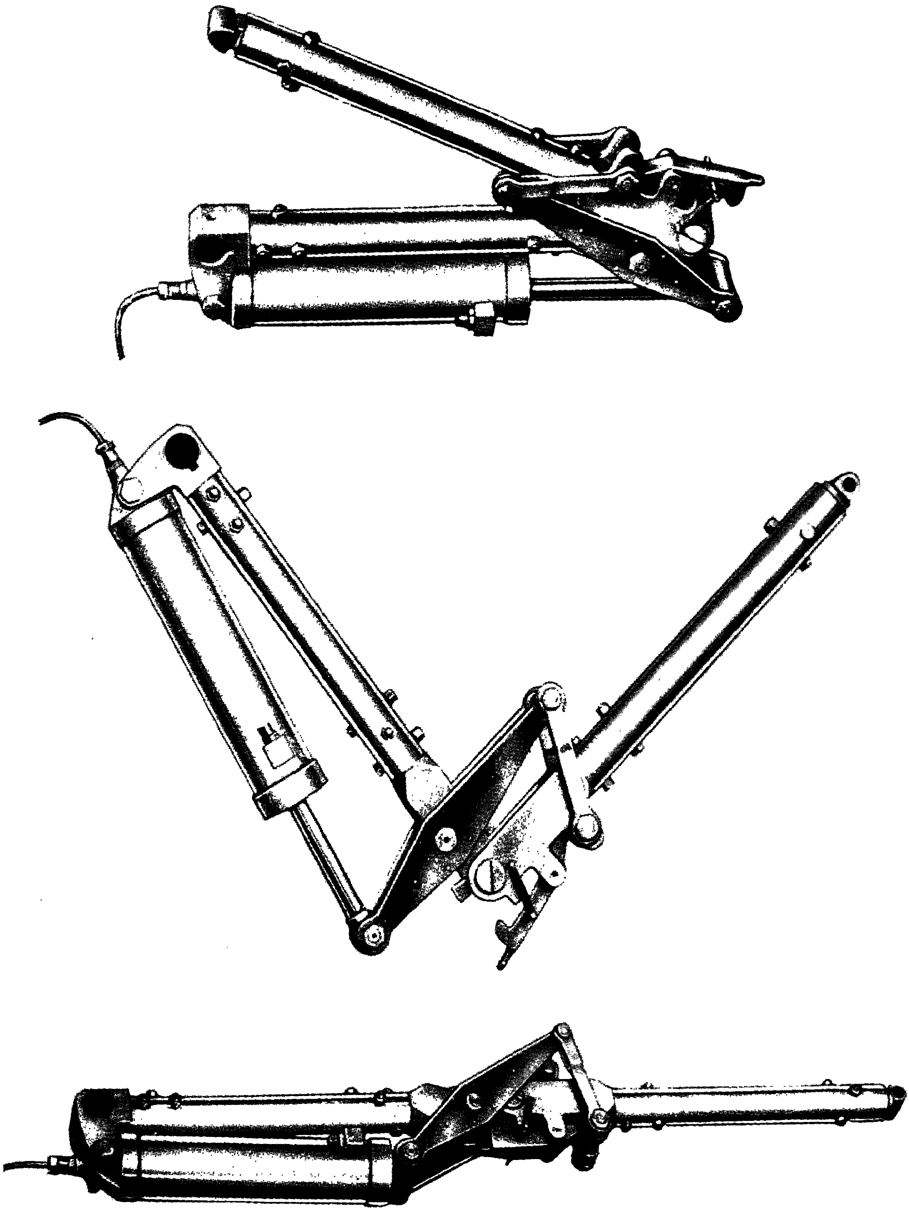


Fig. 61. Nutcracker Strut on Undercarriage shown in Fig. 60

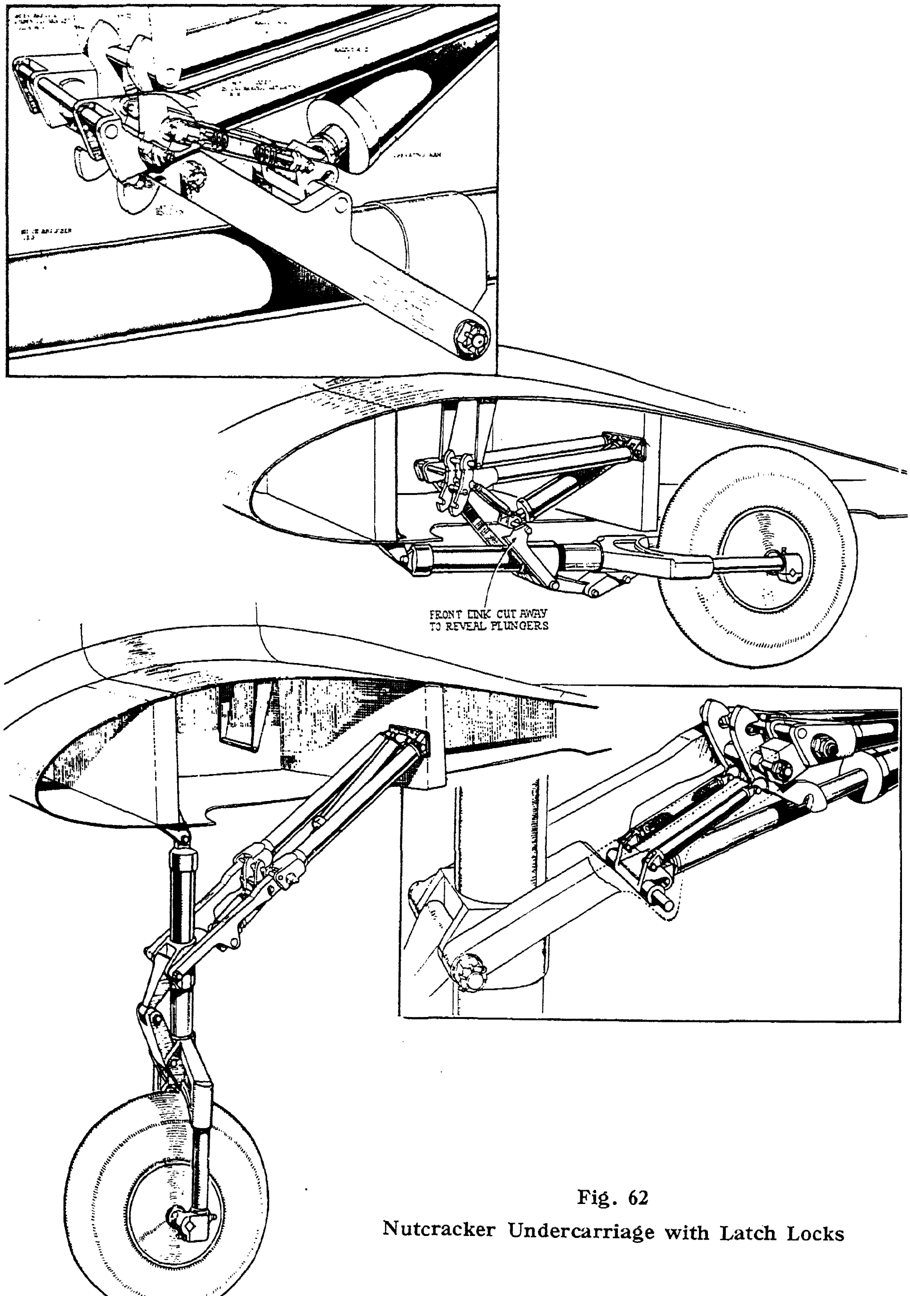


Fig. 62
Nutcracker Undercarriage with Latch Locks

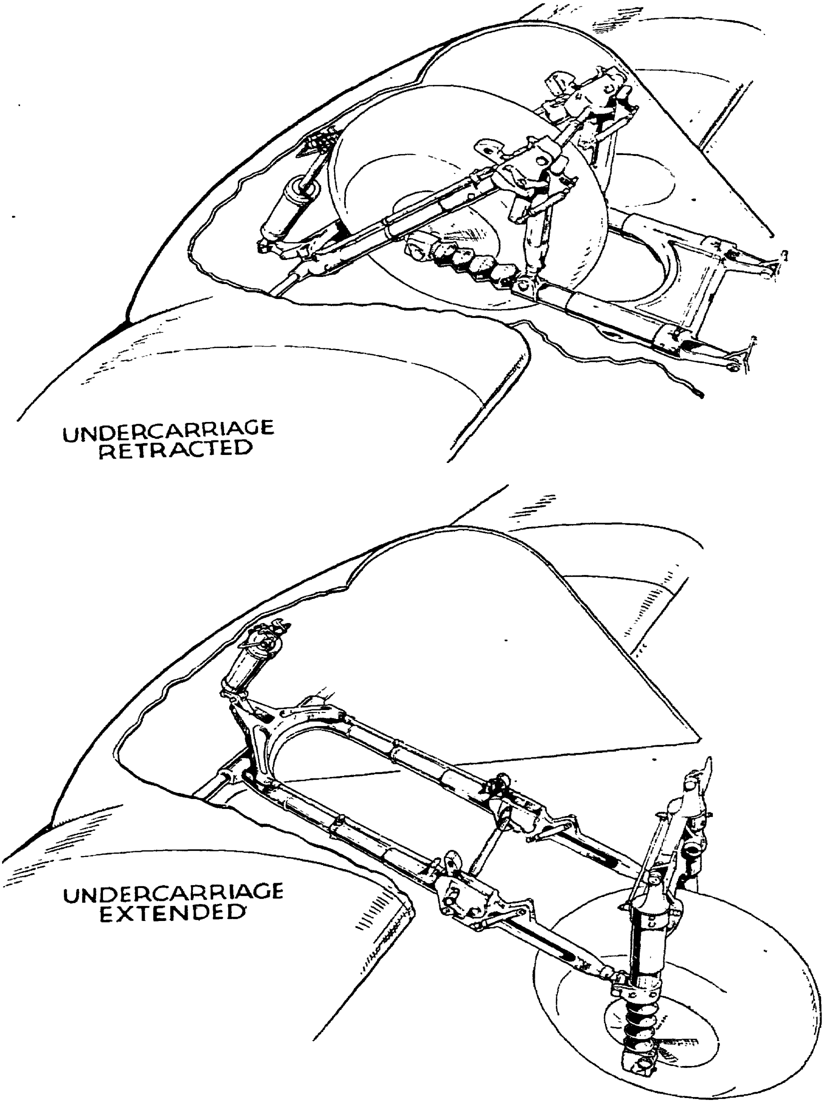


Fig. 63. Dowty Rearward Retracting Undercarriage

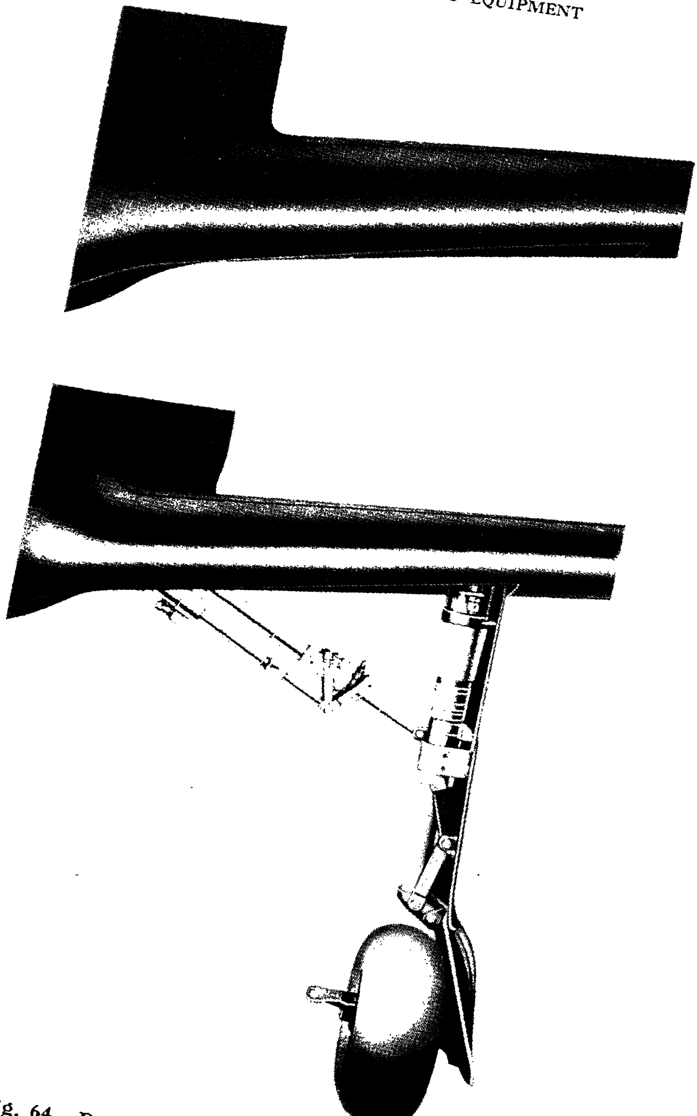
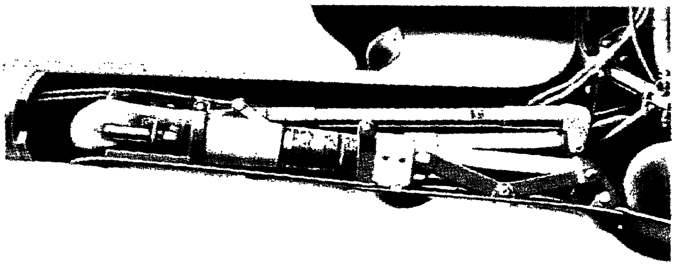
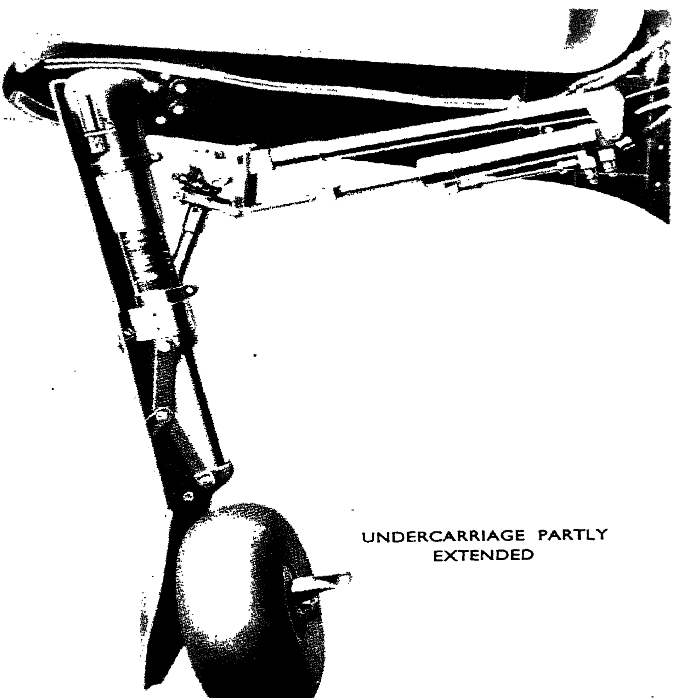


Fig. 64. Dowty Nutcracker Undercarriage



UNDERCARRIAGE RETRACTED



UNDERCARRIAGE PARTLY EXTENDED

Fig. 65. Dowty Nutcracker Undercarriage

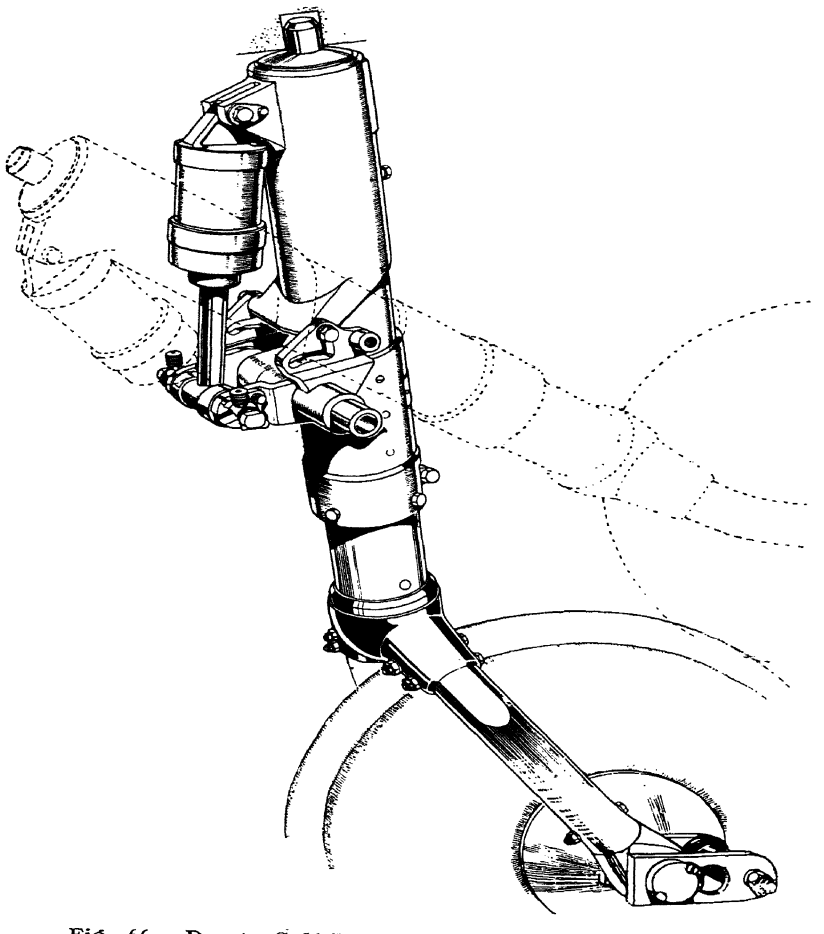


Fig. 66. Dowty Self-Locking Retracting Tail Wheel

CHAPTER XIV

RETRACTING TAIL WHEEL UNITS

THE modern high performance aeroplane is provided with a retracting tail wheel unit to reduce drag. Fig. 67 shows a retracting tail wheel of a type used on a number of aircraft.

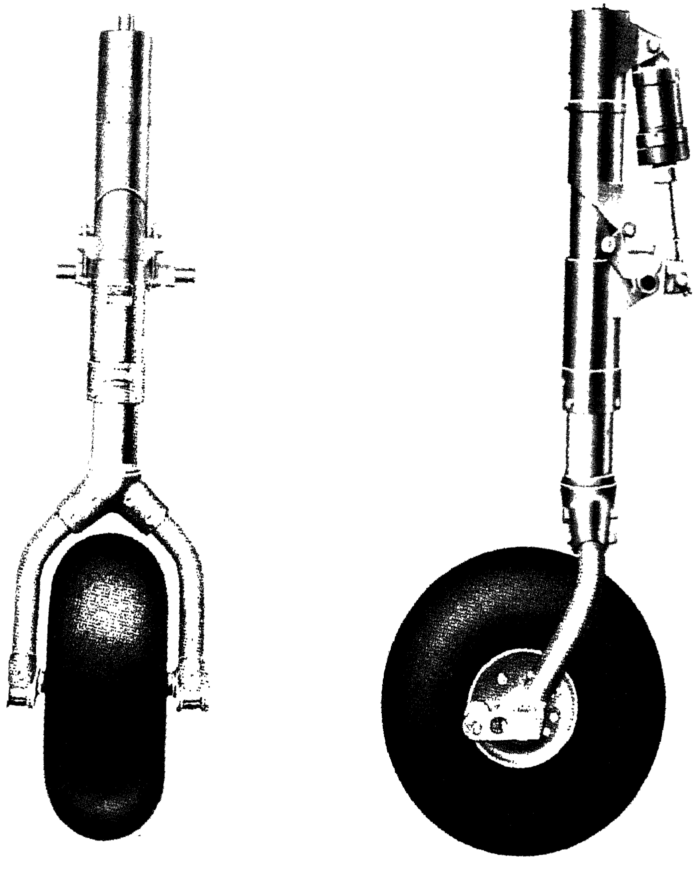


Fig. 67. Dowty Self-Locking Retracting Tail Wheel

This is a self-locking unit in which a pin-jointed jack effects retraction and lowering. In addition, this jack operates the locking plunger to hold the unit in the extended position for landing.

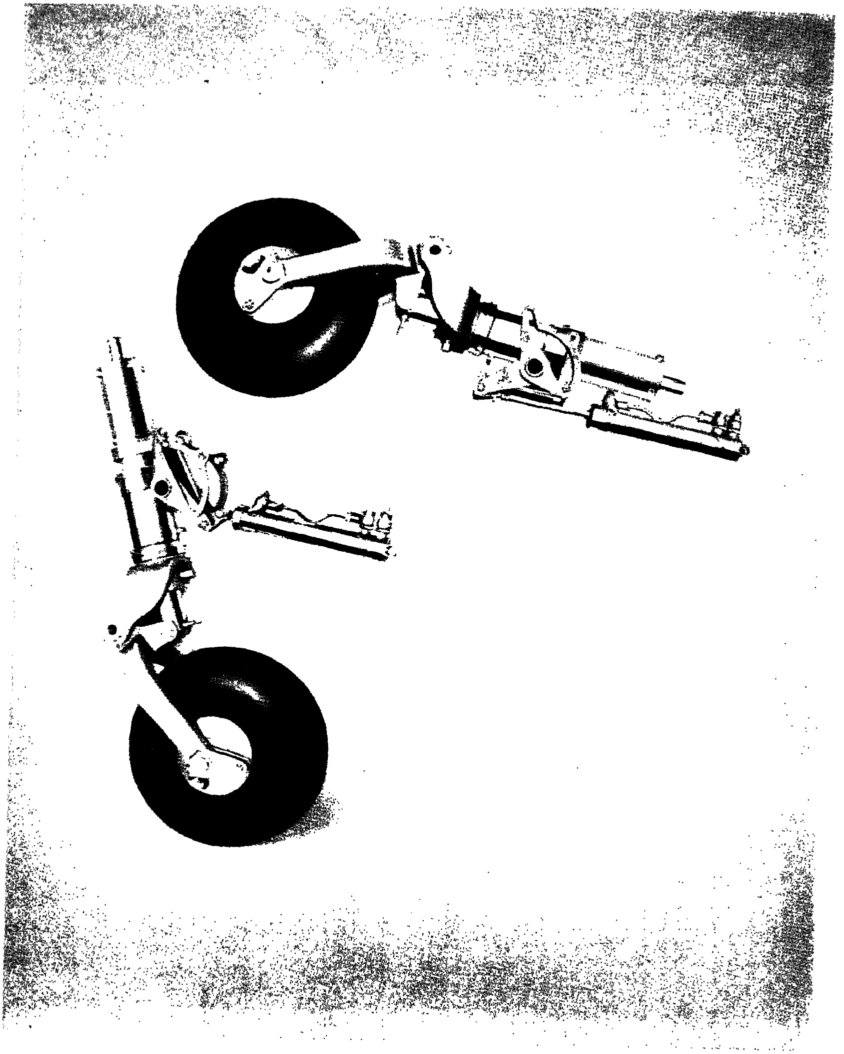


Fig. 68. Dowty Levered Suspension Retracting Tail Wheel

The plunger, situated at the top of the unit, is attached to a sleeve sliding on the outside of the main shock absorber member, and the lower end of this sleeve is provided with a cross pin engaging with curved slots in brackets. These brackets are rigidly attached to the cross shaft on which the unit rotates. The slots are so shaped that the first part of the operating jack movement withdraws the locking plunger from its socket on the aircraft structure without imparting rotational movement to the unit. After the plunger has been completely withdrawn, a moment is produced about the pivot, causing the pin to travel round in an arc, thus swinging the shock absorber into a horizontal position. In the reverse direction the first part of the jack travel swings the tail wheel into the landing position. Then a vertical extension of the slot allows the jack to travel still further and so force the locking plunger home. The oil supply to the jack is fed through a glanded swivel joint where the piston rod anchors to its brackets. This enables rigid pipes to be used and oil is conducted from the swivel joint to the cylinder, through passages provided in the piston rod. A jack of this type is described in Chapter VI.

Fig. 66 illustrates the operating principle of this unit.

Another type of retracting tail wheel unit incorporating levered suspension, which is resilient to horizontal and vertical loads, is shown in Fig. 68. This unit also incorporates a lock operated by free travel of the retracting jack which in this instance is pin-jointed between a lever attached to the shock absorber body and a fitting on the aircraft structure.

The same method of operating the locking plunger is employed as described for the previous unit.

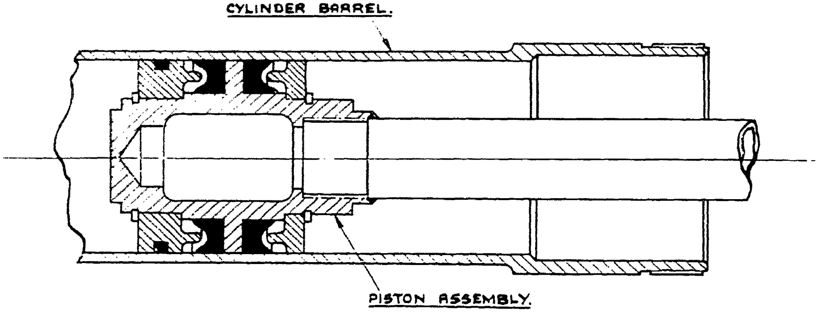


Fig. 69. Piston Assembly in Jack Cylinder

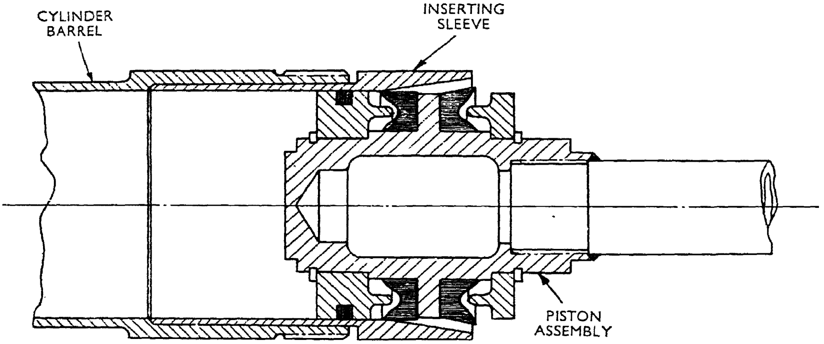


Fig. 70. Method of Inserting Piston Assembly

CHAPTER XV

DISMANTLING AND ASSEMBLING HYDRAULIC UNITS

IN dismantling and re-assembling any hydraulic components great care should be taken to see that the gland rings or piston rings, usually of synthetic rubber, are not damaged.

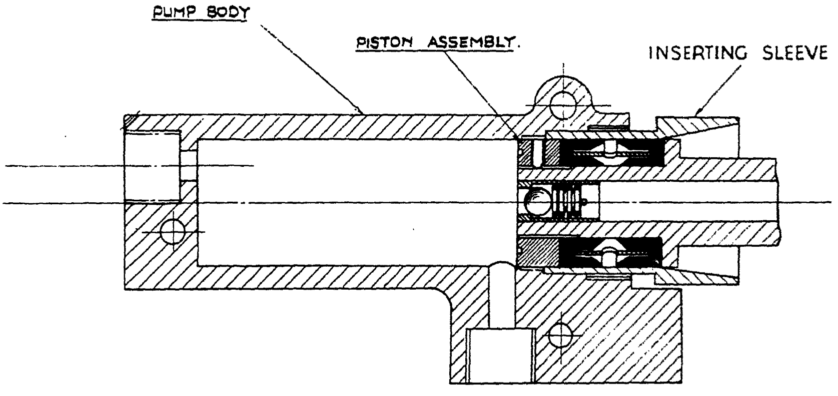


Fig. 71. Inserting Piston into Hand Pump Body

To obtain an effective seal against oil leakage the gland rings, or piston rings, are provided with a thin lip. This can be easily damaged by abrasion and if this occurs leakage will result. When these rings are "in situ," the inside and outside walls are parallel, but before insertion these have a pronounced flare to exert pressure on the cylinder and piston rod or other sealing surfaces. To quote a practical example: a ring designed to provide a seal inside a 3″ bore cylinder will probably be $3\frac{1}{16}''$ diameter before insertion. Therefore, it is necessary to insert a ring of considerably larger diameter than the cylinder bore without damaging the rather fragile ring.

This difficulty is aggravated if it is necessary to push the ring past machined threads in the cylinder or past an oil passage communicating with the bore. It is impossible to accomplish this unless suitable tools are used and it is proposed to describe typical examples.

Fig. 69 shows a piston assembly inside a jack cylinder ; the piston rings which are of larger diameter than the cylinder bore have to be inserted past a shoulder in the cylinder bore which is some distance inside the jack body.

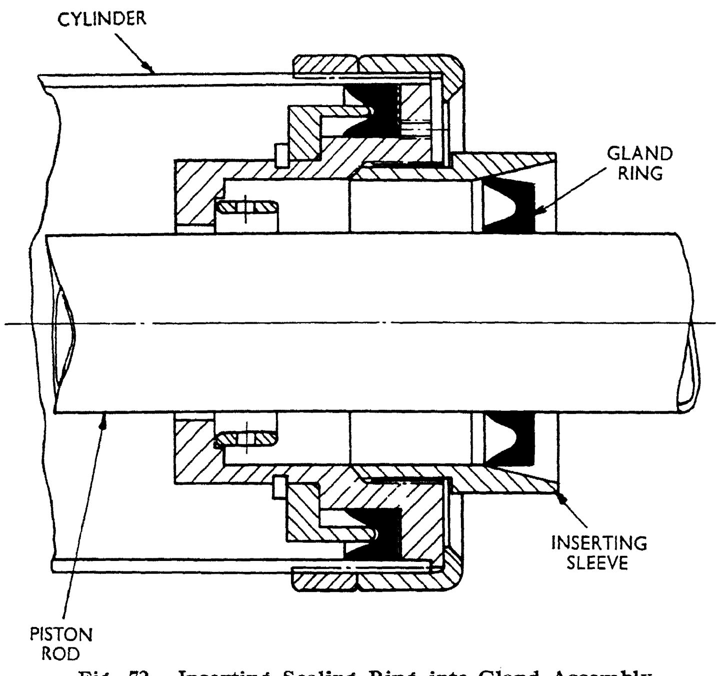


Fig. 72. Inserting Sealing Ring into Gland Assembly

Fig. 70 shows how this is accomplished ; a sleeve provided with a long taper is pushed into the jack body. The piston assembly is fed into this sleeve without difficulty as the taper provides a guide which gradually compresses the lip of the ring.

Fig. 71 shows a piston being assembled into a hand pump body through a similar sleeve.

After the piston unit has been inserted and the sleeve withdrawn, assembly is completed by adding the gland nuts and gland rings. These rings provide a seal between the cylinder and the gland body and also between the gland body and the piston rod. It is common practice for the gland body to be screwed into the cylinder and therefore the outer gland rings have to pass inside the screwed length to their allotted position.

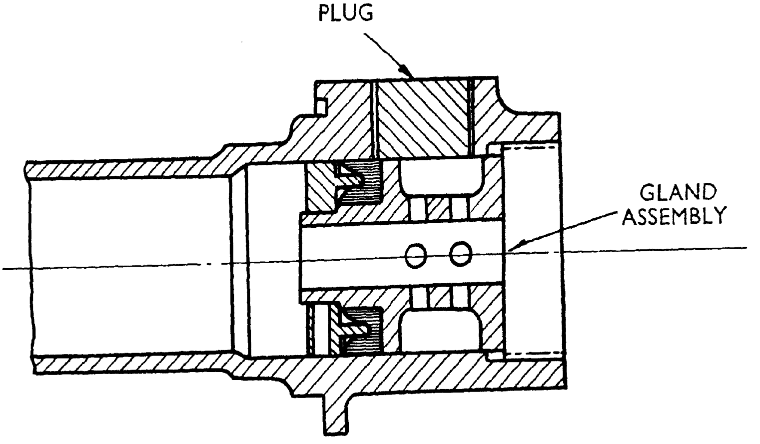


Fig. 73. Using Plug to close Pipe Connection Orifice

This is accomplished by screwing into the cylinder body another sleeve which again is provided with a tapered entry.

A similar sleeve tool for inserting the inner gland rings is shown in Fig. 72.

Where it is necessary for a piston or gland ring to pass across a hole communicating with the cylinder bore, a plug must be inserted to completely fill the hole and provide a flush inner surface for the passage of the ring. This will be understood by referring to Fig. 73. The inner face of the plug must conform to the sectional contour of the cylinder bore.

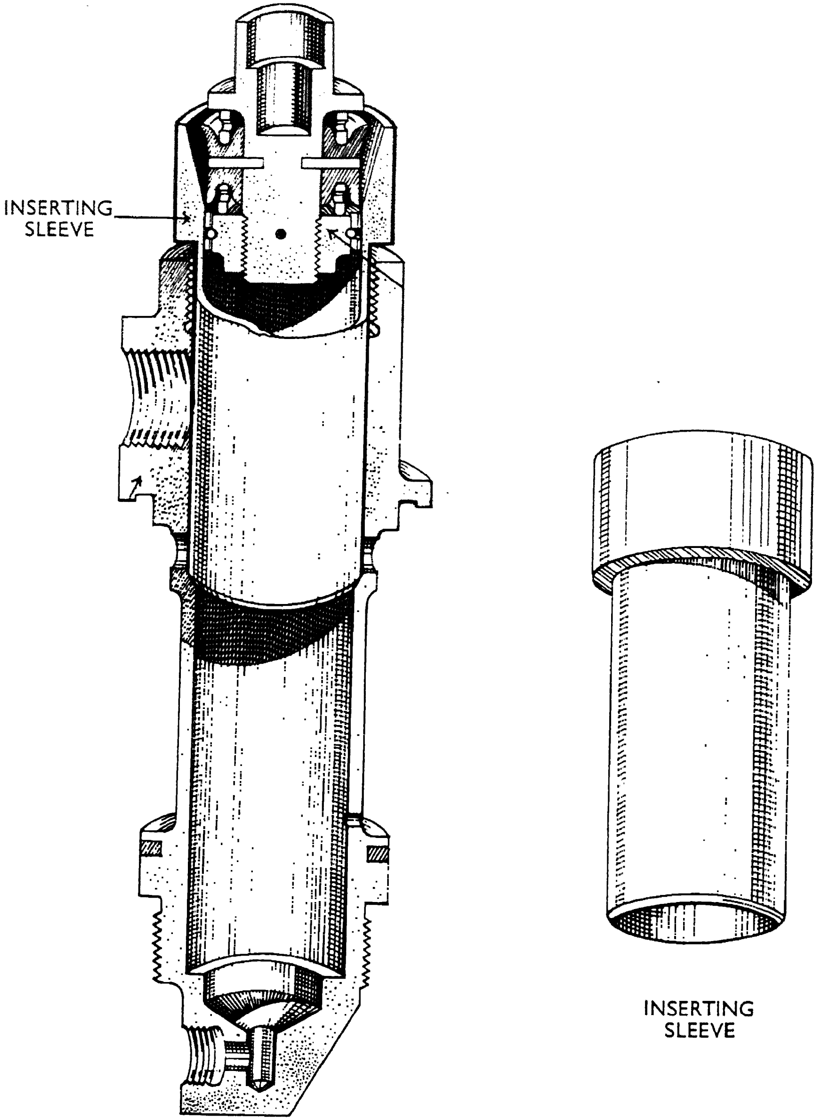


Fig. 74. Sleeve to cover Screw Threads and Union Port

Frequently it is possible to utilise a tool combining the duties of the sleeves and the plugs already described and an example of this type of tool is shown in Fig. 74. The sleeve is sufficiently long to cover the communicating ports in the cylinder body.

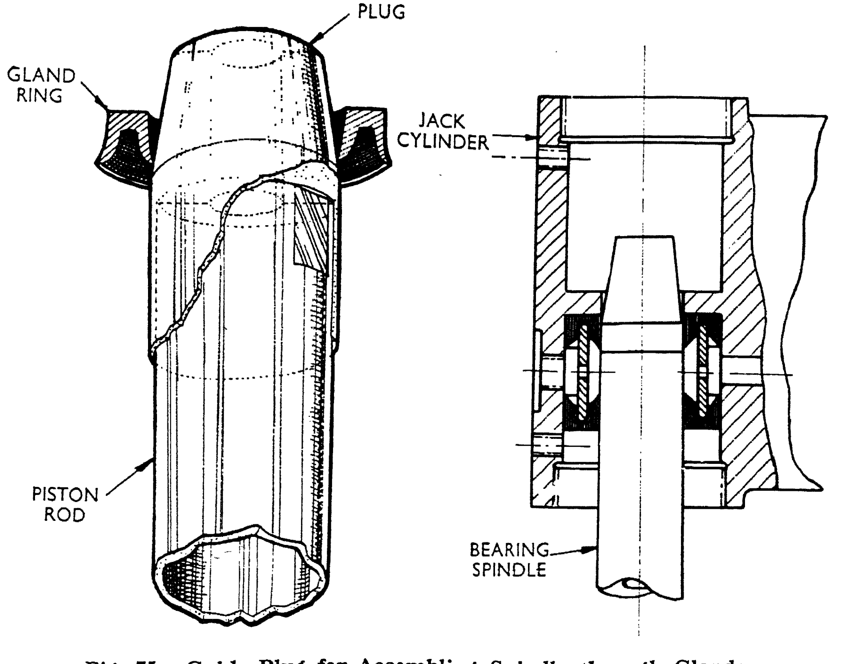


Fig. 75. Guide Plug for Assembling Spindle through Glands

It is sometimes necessary to insert a spindle (which may have a square end) through gland rings which are already "in situ." If this is attempted without the use of proper tools, the lips of the rings will be damaged by the end of the plug. This difficulty is overcome by using a tapered plug which is fitted in or over the end of the spindle to provide a guide, as shown in Fig. 75.

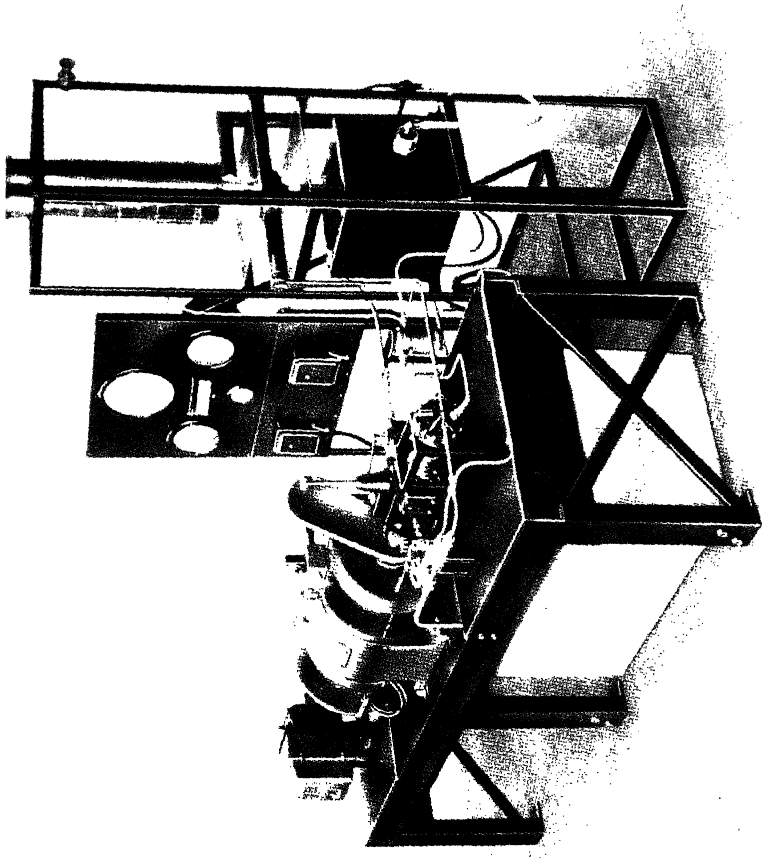


Fig. 76. Test Stand for Engine Driven Pumps

CHAPTER XVI

TESTING

THE Test Shop of a factory producing aircraft hydraulic equipment is one of the most important sections of the works organisation and the equipment provided is of a very extensive and costly nature.

At most aerodromes the facilities available for testing units after overhaul do not compare with those afforded in such a factory, but hydraulic components can be tested on the actual aircraft installation, and methods of carrying out such tests are given later in this chapter.

Fig. 76 illustrates a typical engine pump test bench. The pump is driven by a variable speed electric motor coupled through a four speed gear box ; with this combination the pump can be run at any desired speed.

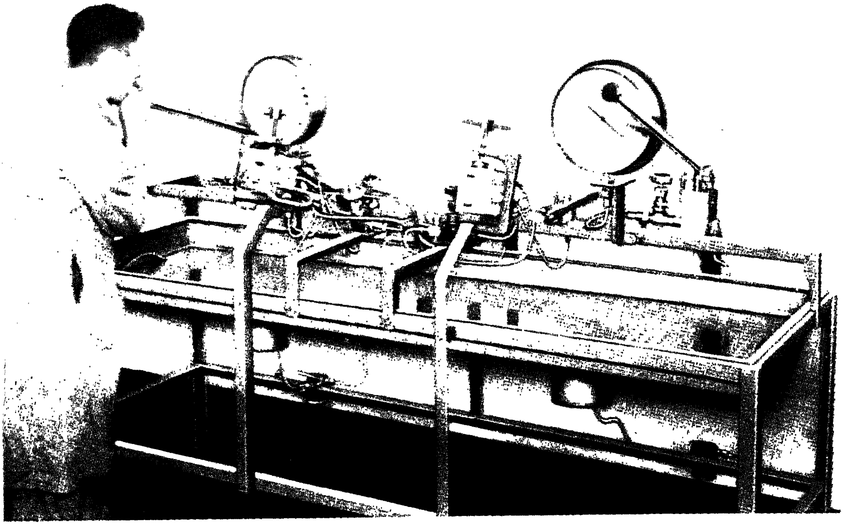
Instruments are provided for recording pump revolutions per minute, delivery pressure, pump temperature, and horse power absorbed. A graduated tank measures delivery output.

The bench acceptance tests for an engine-driven pump commence with a static high pressure test for leakage on the complete pump at 10% in excess of the maximum working pressure. The pump is then run for 45 minutes at maximum cruising r.p.m. delivering oil under no pressure, then a further 10 minutes at normal working pressure, followed by 5 minutes at maximum pressure. A high speed test follows at 25% in excess of the maximum all-out level speed r.p.m., again from zero to maximum pressure.

On conclusion of these tests the pump is dismantled for detail inspection and, after reassembly, the pump is subjected to a second series of tests similar to the first.

Finally a calibration test is carried out to check delivery of the pump throughout its speed range at normal working pressure, and during this test a check is taken to ensure that no appreciable leakage takes place where the driving spindle passes through its gland.

Fig. 77 shows hand pump stands for testing control valves, jacks, relief valves, etc. Each incorporates a reservoir, hand pump, drip tray, filter, relief valves and screw-down cocks. Special stands are employed for testing automatic cut-outs and other units and these include an engine-driven pump, accumulators, jacks, valves and pressure gauges.



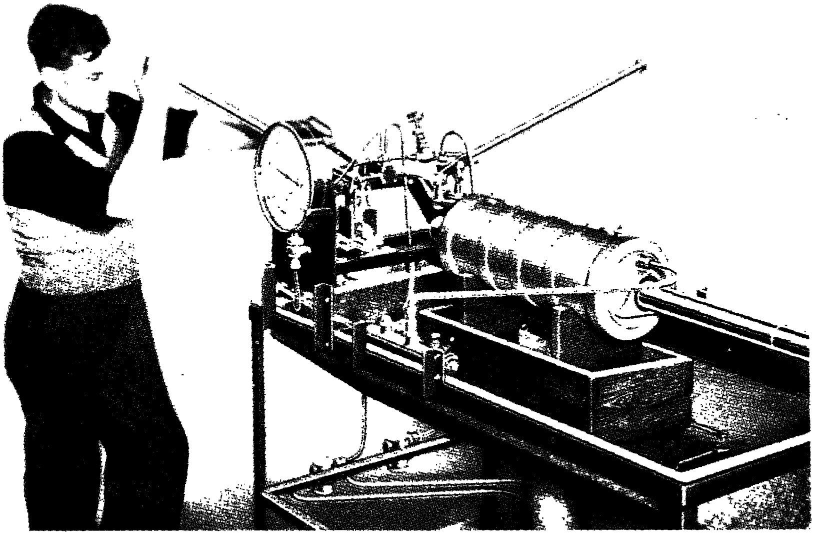


Fig. 77. Hand Operated Test Stands for Jacks, Valves, etc.

Finally, the complete hydraulic installation as fitted in the aircraft is tested to ensure that the system functions satisfactorily. A typical test installation is shown in Fig. 78.

The lengths of all the pipes are identical with those on the aircraft and the positions of all pipe junctions, tee pieces and bends are faithfully reproduced.

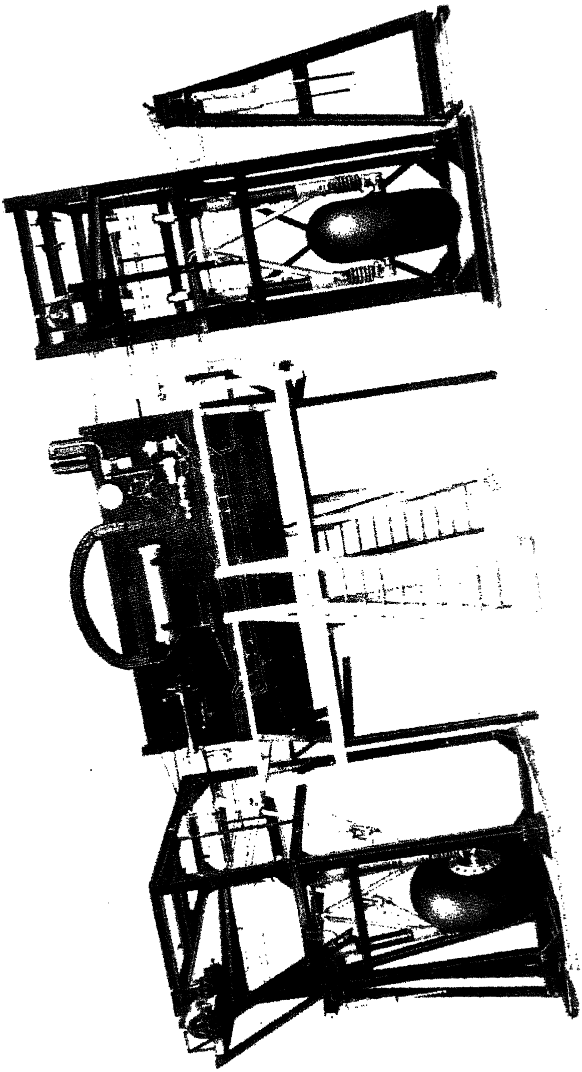


Fig. 78. Test Rig for Complete Aircraft Hydraulic Installation

The following are tests which can be carried on the aircraft.

METHODS OF TESTING UNITS

Instruction No. 1—Hand Pumps

Disconnect outlet pipe and blank off outlet connection on pump by means of a blind end union nut. This may be accomplished by inserting a washer of fibre or metal in an ordinary A.G.S. union nut, or alternatively by placing a steel ball in the end of the union body and holding it in position by the nut.

If the pump is in order it will not be possible to operate the handle after one or two strokes, as sufficient back pressure will be built up to prevent any movement.

If it is possible to move the handle the fault is due to either leaking valves or a defective piston.

Examine the valves to discover if any foreign matter is preventing the balls from seating properly. If the valve seats are scored or show traces of " hammering " it is usually sufficient to drop the ball on its seat and give a sharp blow to the ball by means of a hammer and punch, failing which the seat should be lightly lapped in.

If the valves are in order examine the piston rings or cups, which are usually of synthetic rubber or bonded fabric. Rings or cups which are torn or frayed should be replaced.

Instruction No. 2—Rotary Control Valves

Disconnect both pipe lines leading to the jack and blank off one of the jack connections in the valve body in the manner previously explained in the notes for testing pumps.

Couple hand pump to inlet connection on valve and set control handle so that the blanked off connection would be the feed to the jack. Operate the hand pump and watch the open connection on the valve to see if oil escapes.

If the valve is in order back pressure will be built up, preventing movement of the pump handle. If, however, oil escapes through the open connection, dismantle valve and examine the seatings for damage or foreign matter. This test should be carried out blanking off each jack connection in turn.

Instruction No. 3—Relief Valves

Insert a pressure gauge in the pipe line between the hand pump and relief valve and disconnect the blow-off pipe from the valve. Operate the hand pump very slowly and check that oil escapes from valve only when the correct pressure has been built up. The correct operating pressure is stamped on all relief valves.

A screwed adjustment is provided for the relief valve spring and this will enable resetting to be carried out without trouble.

Instruction No. 4—Automatic Cut-out Valves

1. *Test for external leakage.* Blank off connections (D) and (R) (shown in Fig. 79) then connect a hand pump with a pressure gauge in the pipe line to union (O.) Actuate pump until the pressure reaches 1,200 lbs. per square inch. This pressure must be maintained and no leakage be apparent at any of the sealing washers under unions or plugs.

2. *Test for non-return valve and piston.* With unions (O) and (R) open couple a hand pump to connection (D) and pump pressure to 400 lbs. per square inch. This figure should be maintained with no leakage apparent at connections (O) and (R.) Gradually increase the pressure until it reaches 1,200 lbs. per square inch; over this range the same conditions must be fulfilled. A leakage at (O) will indicate a faulty valve (C) or a faulty washer under the seat (A). The valve may be lapped on its seat with very fine emery paste, care being taken to ensure that this is thoroughly removed before further tests are carried out. If replacement of the valve appears necessary, both valve and seat must be renewed since they are lapped together. Leakage appearing at (R) indicates a faulty piston ring (V) or an insufficient seal at plug (L).

3. *Test for by-pass valve.* Remove spring (T) and replace by a tubular sleeve of approximately the following dimensions, $\frac{13}{16}''$ outside diameter $\times$ 16 gauge $\times$ 3.15″ long, then blank off union (D), couple hand pump to connection (O) and build up a pressure of 800 lbs. per square inch. This figure should be maintained and any drop in pressure will probably be accompanied by leakage at union (R), indicating a faulty valve (N) or an insufficient seal at washer (AA). A slight leakage at these points may be ignored as this will not affect functioning in service, but anything excessive must be corrected. The valve may be lapped in with fine emery paste, again taking care to ensure scrupulous cleanliness before final assembly. Leakage at washer (AA) may be cured by renewing this washer.

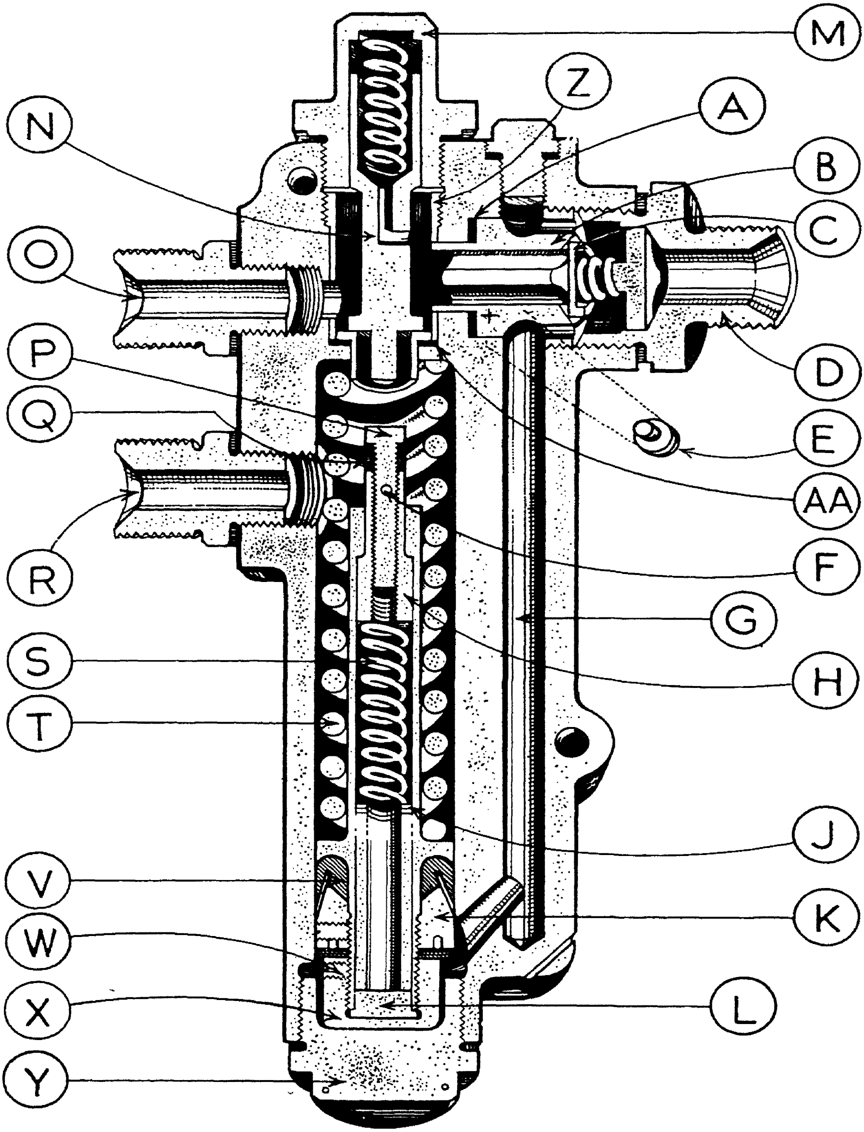


Fig. 79. Reference Diagram for Cut-out Valve Tests

4. *Test for cut-in and cut-out pressures.* The correct figures for these pressures will be found in the aircraft maintenance notes. Couple the unit to a hand pump, accumulator, pressure gauge and screw down stop valve, as shown in Fig. 80.

If no stop valve is available, blank off pipe where valve is indicated when it is required to close this line.

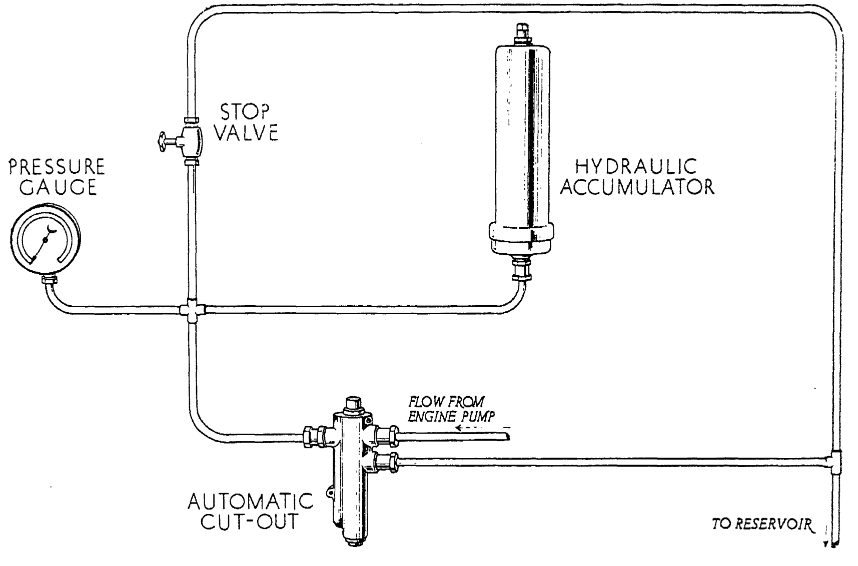


Fig. 80. Piping Diagram for Cut-out Valve Tests

Inflate the air side of the accumlator to a pressure of 120 lbs. per square inch and then close the stop valve. Actuate the pump and build up pressure until the cut-out operates and oil flows from connection (R). The pressure gauge reading should be noted and, if higher than the correct figure, insert shims (J) behind the secondary spring (S) and re-test until the cut-out operates at not more than the above figure. Release pressure by opening stop valve or slackening off blanking union. The cut-in pressure can only be set accurately when an engine driven pump test rig is available, the procedure being as follows: In place of the hand pump connect an engine-driven pump, delivery of which has been adjusted to give the required output. Close the stop valve and build up pressure

until the cut-out operates and oil flows from (R). Slightly open the stop valve so that the pressure is released gradually. Watch the pressure gauge closely and note the figure to which it drops before suddenly building up again to cut-out figure. Should it be lower than the correct cut-in pressure, withdraw the piston assembly and screw pin (P) further into plunger (H) until the error is corrected. Alternatively, if it is higher, unscrew the pin until correction is made. With the cut-in pressure finally adjusted, note the reading on the gauge when the cut-out operates, and oil is by-passed through (R). If this is too high *add* shims (J) one by one until the unit will operate correctly. If too low *remove* shims until the error is compensated.

Instruction No. 5—Jacks

Disconnect the pipe from one end of jack and pump oil through the opposite connection until the piston completes its travel. Continue pumping and watch the open connection for escape of oil. If the jack piston is in order no further oil will escape from the open connection after completion of travel but if oil continues to flow from this connection a defective piston is indicated.

To remedy this, dismantle jack and examine piston cups or rings. If these are damaged they must be replaced but, if they appear sound, check for the fit of these rings or cups in the cylinder barrel.

Pistons fitted with S.E.A. type piston cups should be checked to ensure that piston nut is gripping the cups tightly to avoid leakage round the faces of the cups and along the outside of the piston rod.

Check each end of the jack by disconnecting the pipe connections in turn.

If piston rod gland is leaking, dismantle the gland rings and examine for damage and fits in their housing and on the piston rod.

Gland rings of the S.E.A. bonded fabric type may be adjusted carefully by means of the screwed gland nut, but care should be taken not to overtighten. Gland rings of synthetic rubber must be adjusted to be finger-tight only.

Other units such as accumulators and emergency air shuttle valves cannot be adequately tested on the aircraft installation.

Instruction No. 6—Bleeding System of Air

It is essential that all air be removed from pipe lines and hydraulic units ; failure to do this may result in a broken engine driven pump. If air is allowed to remain in the pipe lines the automatic cut-out will not function properly, consequently the engine pump will be working under pressure for long periods which will ultimately cause a partial seizure. Ensure that the oil reservoir is filled. If jacks are fitted with bleeder screws, slacken screws at one end of the jacks and pump oil in at the opposite end until the pistons have completed their travel, then close bleeder screws and open those at opposite ends of jack, and operate jacks in reverse direction.

If this procedure is carried out several times all air in the system will be eliminated. If jacks are not provided with bleeder screws pump oil in through one connection and slightly slacken off the union nuts on the pipe connections at the opposite ends of jack to allow air to escape ; when "solid" oil emerges from the loosened connection tighten the union nuts. Care should be taken to ensure that bleeder screws and pipe couplings are locked after bleeding has been carried out.

INSTALLATION NOTES

1. All pipes should be cleaned internally as thoroughly as possible after the ends have been belled. Trouble can arise as the result of metal filings being left in the pipes after cutting the ends.

2. Take care to ensure that olives in pipe couplings are correctly aligned. A slightly crossed olive can cause a considerable rise in operating pressure due to the local restriction.

3. When fitting jacks always pump the piston to the end of its travel and then adjust the screwed end of the piston rod before coupling to the operated unit. If this procedure is not carried out the travel of the piston will be limited by some part of the aircraft structure and very heavy loads will be set up.

TRACING TROUBLES

DEFECT	POSSIBLE CAUSES	REMEDY
Jack fails to operate, or operates slowly	(a) Insufficient Oil.	Top up Reservoir with oil.
	(b) Defective Pump.	Test Pump as per Instruction No. 1.
	(c) Defective Control Valve	Test Valve as per Instruction No. 2.
	(d) Defective Relief Valve.	Test Valve as per Instruction No. 3.
	(e) Defective Cut-out Valve.	Test Cut-out Valve as per Instruction No. 4.
	(f) Defective Jack.	Test Jack as per Instruction No. 5.
	(g) Air in pipe system.	Bleed system as per Instruction No. 6.
Automatic Cut-out Valve cuts in and out repeatedly.	(h) Leaking Control Valve.	Test Control Valve as per Instruction No. 2.
	(i) Obstruction in pipe line.	
	(j) Cut-out incorrectly adjusted.	Test Cut-out Valve as per Instruction No. 4.
Cut-out Valve fails to operate at end of jack travel.	(k) Dirty Filter causing heavy back pressure.	Dismantle and clean Filter.
Jack operates, but slowly returns to original position.	(l) Defective Jack Piston.	Test Jack Piston as per Instruction No. 5.
	(m) Defective Control Valve.	Test Control Valve as per Instruction No. 2.
	(n) Leaking Cut-out Valve.	Test Cut-out Valve as per Instruction No. 4.

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